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British Locomotives in 1922.

DESIGNS AND WORK.

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Figs. 1 to 6, pp. 209 and 211.

I — Designs.

The year 1922 is probably unique in that, while only six new locomotive designs require reference, besides which there is very little calling for special comment, of these six, four are notable to a remarkable degree, the fifth is a rebuild of a distinctly progressive character, and the sixth introduces to these articles, for the first time, a main line high-speed heavy-traffic electric locomotive. Two of the new designs are main line express passenger steam locomotives of the 4-6-2 type, hitherto found only on the Great Western Railway, and even there represented only by one engine, now about fourteen years old, which has all this time constituted the only main line *Pacific* locomotive on British railways. The two new classes, one on the Great Northern and the other on the North Eastern Railway, are also distinguished by the fact that they both have three high-pressure cylinders, and in each case the cranks are 120° apart, though the Great Northern locomotive operates the valve gear of the inside cylinder from those of the two outside cylinders, whereas the North Eastern locomotive includes three separate valve gears. Both designs include boiler dimensions and constructional features of special interest, as well as having other notable characteristics, as will be set forth later.

Next there are two remarkable tank engine designs. One a two-cylinder 4-6-4 class introduced on the Glasgow & South Western Railway for heavy express work of a short distance character. The other a 0-6-0 tank engine for difficult local traffic including four cylinders operating cranks very unusually arranged, rendering the design the most exceptional of any of those to be considered.

The remaining steam design is the conversion of an older 4-4-0 class on the

London, Brighton & South Coast Railway to give much greater power and with considerably increased dimensions.

The North Eastern Railway main line electric locomotive design referred to is as notable as any of the steam designs to be described, in that it is the first electric locomotive to be placed in service on a British railway for working traffic analogous to that operated by the standard steam express locomotive classes. It is, in fact, designed to perform substantially the same duties as those given to the North Eastern 4-6-2 steam engine already mentioned, and to meet even more difficult demands. It has been constructed, in view of anticipated main line electrification, for trial and demonstration purposes, and though it has been tested, and will be made the subject of continued experiments, on an electrified freight line, there is, as yet, no track where it can be used under the conditions for which it is designed.

These six engines together provide an exceptionally interesting series, and each calls for more extended description than usual. As, however, and somewhat strangely, there is hardly anything to be said concerning other and less notable designs, instead of giving dimensions in separate tabular form as usual, such particulars are given in the course of description, except that those of the two *Pacifics* are combined to assist comparison.

Figure 1 illustrates the first of two 4-6-2 locomotives constructed at the Doncaster Works of the Great Northern Railway (1) to the designs of Mr. H. N. Gresley, C. B. E., chief mechanical engineer. As already indicated, this engine, named *Great Northern*, and No. 1471, *Sir Frederick Banbury*, of the same class, were the first to break the « splendid isolation » of the Great Western Railway four-cylinder 4-6-2 engine, No. 111, *The Great Bear*, built so long ago as 1908. The latter was designed rather to show what was possible, even with the restrictions of the British load gauge and of weight limits. As such it has justified itself, though the design was never multiplied, mainly because the 4-6-0 classes could meet all practical requirements, and there was only limited call for so large and powerful an engine.

In the case of both the Great Northern and the North Eastern Railways, however, both now included in the new London & North Eastern Railway, the growing weight of trains requiring to be worked « solid » between London and Edinburgh, as well as of other important trains, some at higher speed, and the severity of the gradients on many sections, rendered a design of this class a certainty of the future. It is probable, indeed, that it would have appeared earlier had it not been for the war and its immediate and indirect influences.

In the Great Northern engine the three cylinders all actuate the middle coupled axle, those outside being approximately horizontal, while the inside cylinder is inclined so that its connecting rod clears the leading coupled axle. Two valve gears, of Walschaerts type, only are employed, the valve rods being coupled by a system of levers, as in the case of Mr. Gresley's previous 2-6-0 and 2-8-0 three-cylinder designs (1), so that, although the cranks are at 120°, the desired operation of its valve is obtained through the medium of a floating lever utilising a 2 : 1 ratio. Incidental features of interest are that the main rods and other

(1) As this article deals with the designs of 1922 the names then borne by the railways concerned are used, though the respective companies are now combined into four grouped systems.

(1) See *Bulletin of the International Railway Association*, April 1921 and March 1922.

parts are of nickel chrome steel, heat treated, the rods being hollow, in order to realise a considerable reduction in weight, while providing more than sufficient strength in view of the very great power exerted.

The boiler also is of large dimensions, without, however, excessive length of tubes. The barrel is 19 feet in length, and has a tapered ring at the firebox end, while the firebox itself has its crown-plate sloping downwards towards the rear. The largest diameter of the barrel is 6 ft. 5 in., tapering to 5 ft. 9 in. for the parallel section. The firebox has an extension into the barrel, forming a combustion chamber. A Robinson superheater is fitted, with four rows of eight elements. Ross safety valves, of « pop » type, are used. Wakefield mechanical lubricators are employed. The trailing wheels have Cartazzi radial axle boxes. The cab has side windows and an extended roof. The regulator handles are duplicated at each end of a cross shaft. Power reversing gear is provided. The tender is on eight wheels, but is not of bogie type.

Figure 2 illustrates the first of two *Pacific* locomotives designed by Sir Vincent Raven, K. B. E., chief mechanical engineer, and built at the Darlington Works of the North Eastern Railway. Here, also, the three cylinders operate cranks at 120°, but all drive the leading coupled wheels, and a separate valve gear — Stephenson link motion — is provided for each cylinder. The cylinders are in one casting, with one steam chest common to all, though the exhaust chambers are separate to the bottom of the blast pipe, where they combine. The firebox, of round-topped design, has an extension into the barrel forming a combustion chamber, thus reducing the distance between tube plates to 21 feet. The wheelbase is somewhat longer than in the case of the Great Northern engine, but the tender is smaller, and is carried on six wheels only, so that the total wheelbase is not much increased. The trailing wheels are fitted in radial axleboxes. Three safety valves are mounted one behind another above the firebox. The barrel of the boiler is 6 feet in diameter.

Leading dimensions of these two designs, placed together to assist comparison, are as follows :

	Great Northern Railway. No. 1470.	*North Eastern Railway. No. 2400.*
Cylinders (3)	20 × 26 inches.	19 × 26 inches.
Coupled wheels, diameter	6 ft. 8 in.	6 ft. 8 in.
Bogie wheels, diameter	3 ft. 2 in.	3 ft. 1 1/4 in.
Trailing wheels, diameter	3 ft. 8 in.	3 ft. 9 1/4 in.
Coupled wheelbase	14 ft. 6 in.	15 feet.
Engine wheelbase	35 ft. 9 in.	37 ft. 2 in.
Steam pressure, lb. per square inch	180	200
Heating surface, tubes (large)	835 square feet.	692.7 square feet.
— — — (small)	1 880 » »	1 472 » »
— — firebox	215 » »	200 » »
— — superheater	525 » »	509.9 » »
— — total	3 455 » »	2 874.6 » »
Grate area	41.25 » »	41.5 » »
Adhesion weight	60 tons.	60 tons.
Engine weight (working order)	92 tons 9 cwts.	97 tons.

	Great Northern Railway. No. 1470.	*North Eastern Railway. No. 2400.*
Tender weight (working order)	56 tons 6 cwts.	47 tons 2 cwts.
Water capacity of tender	5 000 gallons.	4 125 gallons.
Coal capacity of tender	8 tons.	5 1/2 tons.
Wheelbase of tender	16 feet.	12 ft. 8 in.
Total length of engine and tender	70 ft. 5 1/8 in.	72 ft. 7 1/4 in.
Weight in working order, engine and tender	148 tons 15 cwts.	144 tons 2 cwts.

Figure 3 illustrates one of the large 4-6-4 express tank engines designed by Mr. R. H. Whitelegg, chief mechanical engineer, Glasgow & South Western Railway, built at the Hyde Park Works in Glasgow of the North British Locomotive Company. These have been designed in view of the numerous routes radiating from Glasgow on which heavy and reasonably fast trains are operated, including several notable schedules, though usually the distances to be covered are not long, rarely exceeding about 40 miles. The design is somewhat similar to one introduced in 1912 by Mr. Whitelegg on the then London, Tilbury & Southend Railway (1), but is based upon Glasgow & South Western Railway standards and practice in regard to details. These engines are also used to some extent between Glasgow and Kilmarnock, a very severely graded section of the route of Anglo-Scottish express trains.

Walschaerts valve gear is employed, while various special features in regard to details are incorporated, including the use of ball bearings for the valve gear connecting rods, piston valves of special type, Robinson pressure relief valves, etc. The superheater is of Robinson type. Steam reversing gear is fitted. The regulator, brake valve, etc., are duplicated on either side of the footplate, to facilitate manipulation, as these engines work equally either way round, for which their « double-ended » design renders them particularly suitable.

Leading dimensions are : Cylinders, 22 by 26 inches; coupled wheels, 6 feet diameter; bogie wheels, 3 ft. 6 in. diameter; rigid wheelbase, 13 ft. 2 in.; total wheelbase, 39 feet; heating surface : large tubes 442 square feet, small tubes 1 132 square feet, firebox 156 square feet, superheater 255 square feet, total 1 985 square feet; grate area, 30 square feet; steam pressure, 180 lb. per square inch; weight on coupled wheels, 54 tons (18 tons on each axle); total weight in working order, 99 tons 1 1/2 cwts.; water capacity of tanks, 2 400 gallons; coal capacity of bunker, 3 1/2 tons.

Figure 4 illustrates another tank engine, of equal if not greater interest, in that it is so marked a departure from ordinary practice, but of very different class and of much smaller dimensions. It is in some respects experimental, but is intended to meet the demands of heavy local traffic between the group of industrial towns around Stoke-on-Trent, in what is known as the « Potteries » district of Staffordshire. Here the trains require to be operated smartly over severe gradients, and with frequent stops and considerable loads.

The new engine, designed by Mr. J. A. Hookham, chief mechanical engineer, and built at the Stoke Works, is unique in that it combines four high-pressure cylinders, each with its own Walschaerts valve gear, in a six-wheeled six-coupled

(1) See *Bulletin of the International Railway Congress Association*, April 1914.

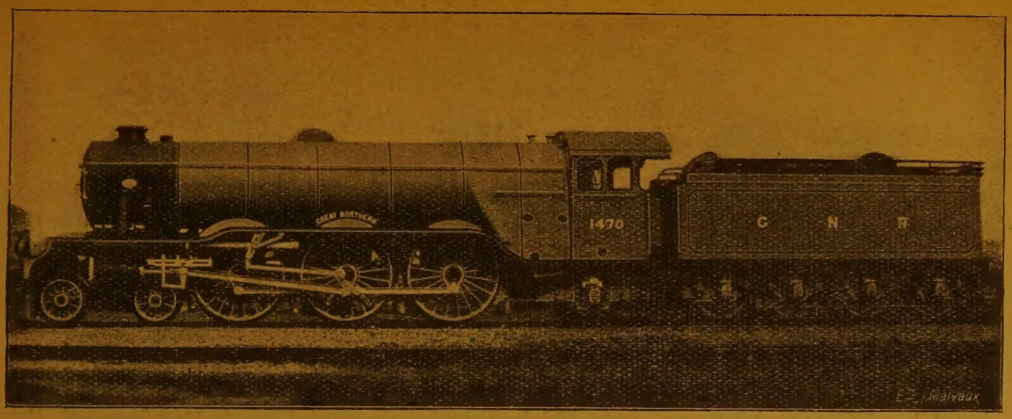

Fig. 1. — Three-cylinder 4-6-2 locomotive, Great Northern Railway.

Mr. H. N. Gresley, C. B. E., chief mechanical engineer.

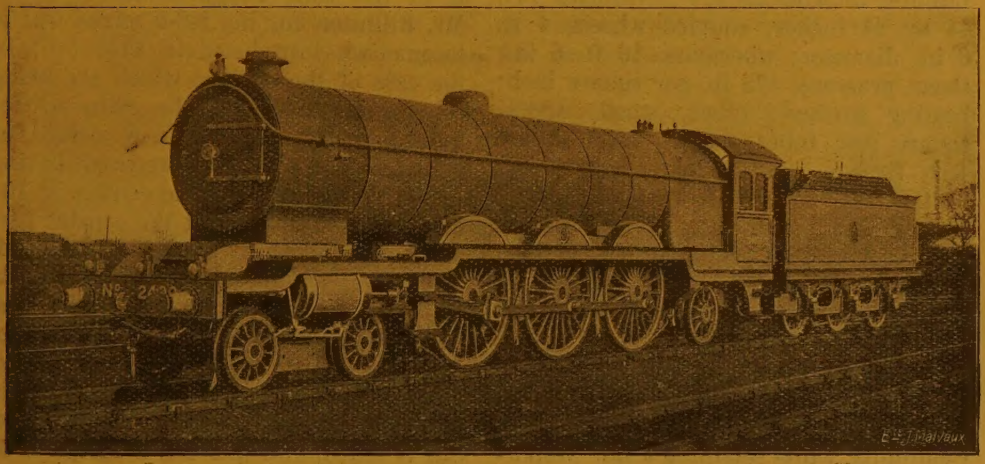

Fig. 2. — Three-cylinder 4-6-2 locomotive, North Eastern Railway.

Sir Vincent Raven, K. B. E., chief mechanical engineer.

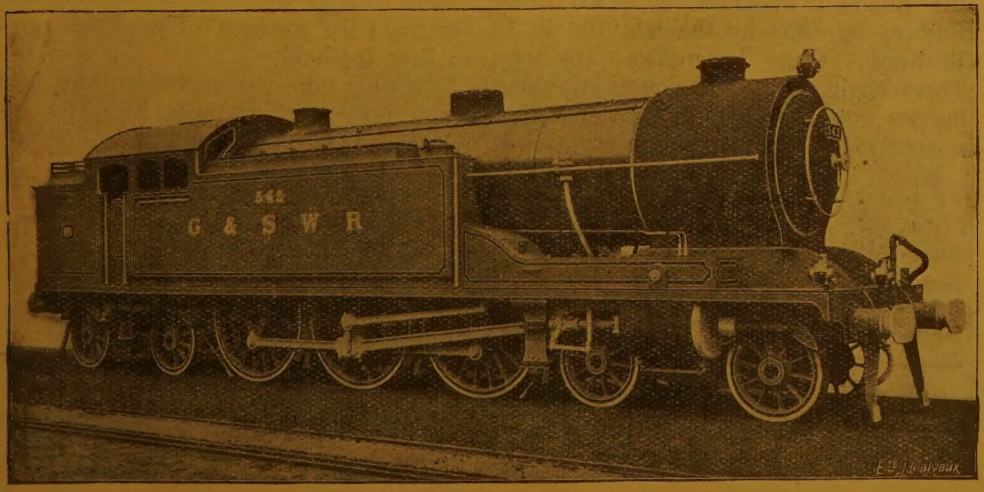

Fig. 3. — 4-6-4 express tank engine, Glasgow & South Western Railway.

Mr. R. H. Whitelegg, chief mechanical engineer.

tank engine, while the cranks are so arranged that each outside crank is at an angle of 135° relatively to the adjacent inside crank, the two inside and the two outside cranks being 90° apart in each case. The object is to give a better turning moment and improved acceleration abilities in difficult suburban traffic involving frequent stops on a route which is severely graded. The engine, as a whole, is relatively small, but includes superheater and other modern adjuncts. Leading dimensions are : cylinders (4), 14 by 24 inches; coupled wheels, 4 ft. 6 in. diameter; wheelbase, 16 ft. 6 in.; steam pressure, 175 lb. per square inch; heating surface : tubes (small) 488.64 square feet, tubes (large) 261.3 square feet, firebox 106.76 square feet, superheater 195 square feet, total 1 051.7 square feet; grate area, 17.52 square feet; weight in working order, 56 tons 13 cwts.

These complete the more exceptional steam locomotive designs of 1922, but, to a certain degree, the rebuilt locomotive illustrated in figure 5 is almost equally remarkable, in that, in process of rebuilding, while retaining a fair proportion of the original engine, a large increase in tractive capacity is secured. The original design was introduced on the London, Brighton & South Coast Railway in 1903 by the late Mr. R. L. Billinton, then locomotive engineer. These engines have, in course of years, become outclassed for the heavier duties, not only for the fast and heavy trains, such as the 60-minute expresses between London and Brighton, but also for the secondary trains, some of which, owing to their weight, and the smart intermediate schedules called for, are probably even more difficult to work.

As the result of rebuilding, however, Lt.-Col. L. B. Billinton, the present locomotive engineer, and the son of the original designer, has produced a class which will meet requirements for a long time ahead. The new superheater boiler is of the same design as that used by Mr. Billinton for his 2-6-0 mixed traffic locomotives introduced in 1913 (1). In the case of the engines which are being rebuilt, as illustrated, the cylinders required replacement. A new design of cylinders was therefore prepared, having piston valves on the same centres as the old « D » valves, so that the greater part of the original valve gear is retained. The valves are designed with two ports to give double admission, while the exhaust ports are as large as possible. The new boiler has a Belpaire firebox, and extended smokebox. Top feed is fitted, also a Weir feed pump. A new cab is fitted, and this has a footplate of honeycomb pattern, with hardened wood plugs. These can be readily renewed, and after hosing the footplate the water drains away along the channels between the sections. This design gives a firm foothold.

Leading dimensions before and after rebuilding may usefully be given for purposes of comparison.

	Before rebuilding.	*As rebuilt.*
Cylinders	19 × 26 inches.	20 × 26 inches.
Coupled wheels, diameter	6 ft. 9 in.	6 ft. 9 in.
Coupled wheelbase	8 ft. 9 in.	10 feet.
Total wheelbase	22 ft. 2 in.	24 ft. 6 in.
Length of boiler barrel	11 ft. 5 in.	12 ft. 6 1/2 in.

(1) See *Bulletin of the International Railway Congress Association*, April 1914.

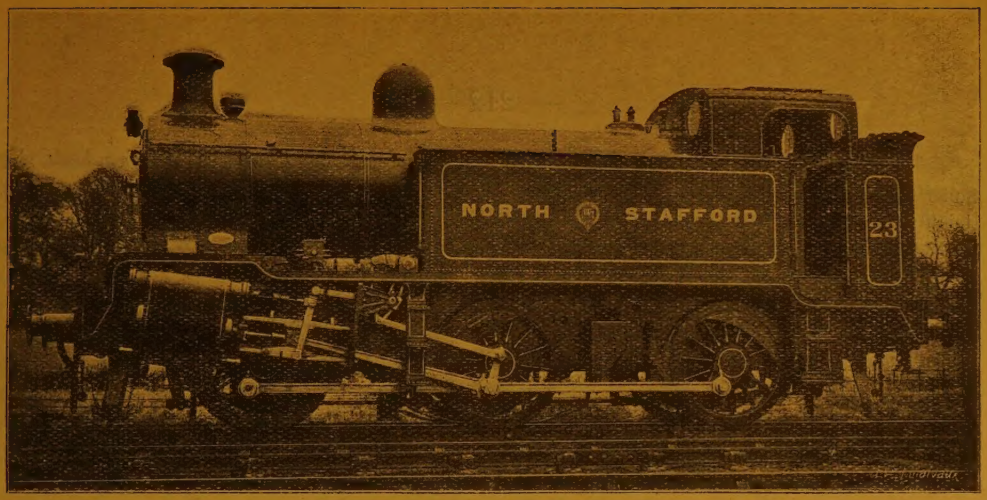

Fig. 4. — Four-cylinder 0-6-0 tank engine, North Staffordshire Railway.

Mr. J. A. Hookham, chief mechanical engineer.

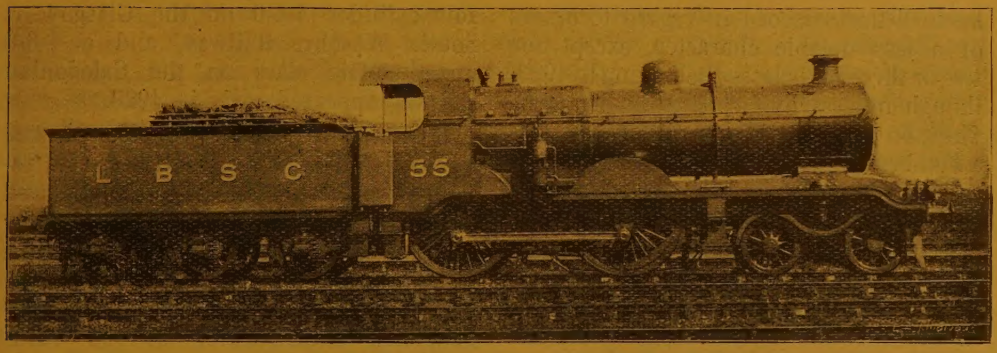

Fig. 5. — Rebuilt 4-4-0 superheater locomotive, London, Brighton & South Coast Railway.

Lt.-Col. L. B. Billinton, locomotive engineer.

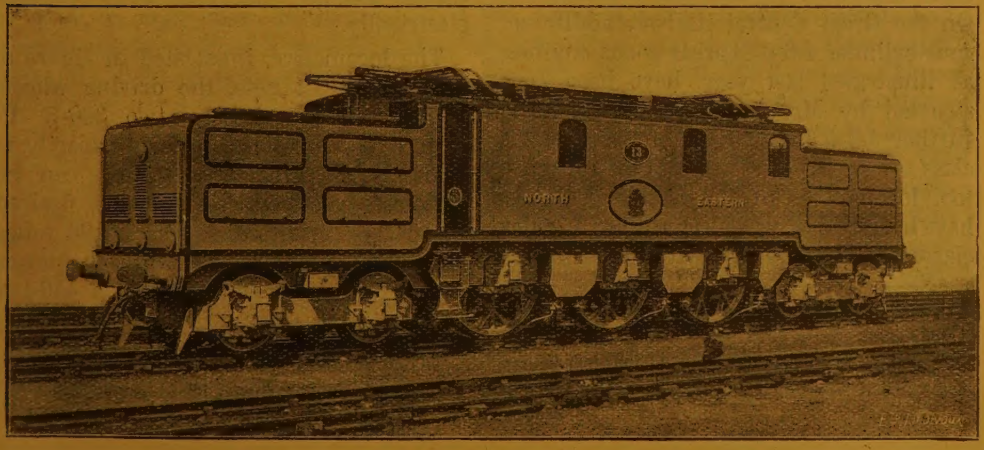

Fig. 6. — 4-6-4 express passenger electric locomotive, North Eastern Railway.

Sir Vincent Raven, K. B. E., chief mechanical engineer.

	Before rebuilding.	*As rebuilt.*
Boiler diameter outside	4 ft. 10 in.	5 ft. 3 in.
Height of boiler centre line	8 ft. 3 in.	8 ft. 10 in.
Heating surface, tubes	1 507 square feet.	1 155.4 square feet.
— — firebox	120 —	139 —
— — superheater	...	279 —
— — total	1 627 square feet.	1 573.4 —
Grate area	23.75 —	24.8 —
Steam pressure, lb. per square inch	180	180
Adhesion weight	35 tons 8 cwts.	37 tons 18 cwts.
Engine weight in working order	51 tons 10 cwts.	58 tons 1 cwt.
Engine and tender weight in working order	86 tons 15 cwts.	97 tons 6 cwts.

The tender has had its water capacity increased from 3 000 to 3 600 gallons.

It is somewhat strange that, besides this series of remarkable designs, there should be so little to record in regard to others of a less notable character, except for two or three new classes belonging to 1923, though necessarily in hand during 1922. Thus, on the Great Western Railway, after a number of years' interval, Mr. C. B. Collett, who has succeeded Mr. G. J. Churchward as chief mechanical engineer, has placed in service several new four-cylinder 4-6-0 locomotives, named after *Abbeys*, but, except in a few small details, of the well-known *Star* class. On the Great Eastern Railway, Mr. A. J. Hill, chief mechanical engineer, has built further engines of the large 0-6-0 superheater class described in last year's article (1). On the Great Central Railway additional four-cylinder 4-6-0 express goods engines, as illustrated last year, have been constructed by Mr. J. G. Robinson, while further 4-4-0 locomotives of the *Director* class are in hand (2). On other railways, too, locomotives of the standard classes have been added, while rebuilding of older classes and equipment with superheaters has proceeded more or less continuously. On the London, Brighton & South Coast Railway Lt.-Col. L. B. Billinton has built further 4-6-4 tank engines (1). A rebuilt four-cylinder 4-4-0 on the Glasgow & South Western Railway, and a 4-6-0 mixed-traffic class on the Caledonian Railway appeared early in 1923.

It is now necessary to consider electric locomotive developments, with special reference to the 4-6-4 main line high-speed heavy passenger design constructed by Sir Vincent Raven, K. B. E., chief mechanical engineer, North Eastern Railway. It has been produced in view of the contemplated electrification of the York-Newcastle main line, but at present can only be used on the Shildon-Newport line, 15 miles in length, where heavy mineral traffic has for some time been operated electrically.

The locomotive, illustrated in figure 6, is of the 4-6-4 type, the driving wheels being each actuated by two 300-H. P. motors, so that the combined capacity is 1 800 H. P. The six motors can be variously grouped to suit the desired speeds. A maximum speed of 90 miles per hour is prepared for, while the power capacity is designed to enable a 450-ton

(1) See *Bulletin of the International Railway Association*, March 1922.

(2) See *Bulletin of the International Railway Association*, April 1921.

(1) See *Bulletin of the International Railway Association*, January-February-March 1920.

train load to be operated at 65 miles per hour on level track.

The motors are mounted in pairs over each driving axle, and drive the latter through pinions gearing with a hollow shaft or « quill », having at each end a « spider », the arms of which mesh with the wheel spokes and engage by means of « quill springs ». The motors are thus carried on the main frame, while at the same time the movement of the axle boxes is allowed for. Direct current is used at 1 500 volts, supplied through overhead conductors. Principal dimensions are : length overall, 53 ft. 6 in.; driving wheel diameter, 6 ft. 8 in.; bogie wheel diameter, 3 ft. 7 1/4 in.; rigid wheelbase, 16 feet; weight on each driving axle, 18 1/2 tons; total weight, 102 tons. An unique feature is that a small boiler for supplying steam for train heating is heated electrically.

Towards the end of 1921, Mr. C. Jones, chief mechanical and electrical engineer of the Metropolitan Railway, placed in service some rebuilt electric locomotives which are now much more powerful than heretofore, and during 1922 nearly all the remainder have been similarly dealt with. They are of the usual double bogie type, but now develop 1 500 H. P., and are designed for maximum speeds of 65 miles per hour, though they do not usually exceed about 50, as their longest non-stop run is only about 10 miles, over a crowded route.

II. — Work.

In October 1921, as mentioned in last year's article, the Great Western Railway restored its pre-war express train schedules almost intact, and has since developed them slightly, including the booking of a second train to make the 2-hour run between London and Bristol *via* the longer route (118 1/2 miles) and to slip carriages at Bath (106.9 miles) in 105 minutes. Other railways have also considerably improved their services, though « standard » times of 4 hours between London and Leeds, Manchester and Liverpool, and 8 1/2 hours between London and Edinburgh and Glasgow have only been modified by a few minutes. As a rule, however, where pre-war times are not restored, this is due to there being additional stops or the increased loads, so that, in fact, if not apparently, most railways are back again to pre-war standards, and in some instances give even better and faster services.

In this connection, reference may be made to the outstanding characteristics of a series of tables analysing British express train services in the summer of 1922, published by the *Railway Magazine* in October last. These showed that there were 34 runs of more than 100 miles between stops on the London & North Western Railway, ranging from 100.7 to 179.2 miles; 26 on the Great Western Railway, 102.3 to 225.7 miles; 18 on the Great Northern Railway, 103 to 156 miles; 9 on the Midland Railway, 113 to 123.5 miles; 9 on the North Eastern Railway, 106.6 to 124.4 miles; 6 on the Great Eastern Railway, 109.2 to 130.2 miles; 5 on the Great Central Railway, 103.1 and 107.6 miles; and 4 on the Caledonian Railway, 100.6 and 102.3 miles. These give a total of 111 such runs, as compared with 138 in 1914. The longest is still that of the Great Western Railway, between London and Plymouth, 225.7 miles in 247 minutes. By far the larger proportion are scheduled at average speeds exceeding 50 miles per hour. A considerable number average over 55 miles per hour, several almost reaching the mile a minute rate, while there are two slip carriage services from London to

Bath, 105 minutes for 106.9 miles, average 61.1 miles per hour.

Including shorter runs three railways now have trains booked at over 60 miles per hour. The North Eastern restored its pre-war schedule of 44.1 miles from Darlington to York in 43 minutes, average 61.5 miles per hour, but with a different and heavier train than in 1914. The Great Central again has a run from Leicester to Nottingham (Arkwright Street), 22.6 miles in 22 minutes, average 61.5 miles per hour. The Great Western slip services mentioned give 61.1 miles per hour schedules, for more than 100 miles, while the trains booked between London and Bristol, start to stop, 118 1/2 miles in 120 minutes, very nearly reach the mile a minute rate. The London & North Western, Caledonian, Midland, Great Northern, and London & South Western also have fastest runs averaging over 55 miles per hour, while every railway, where it could reasonably be expected, has at least one train scheduled at over 50 miles per hour.

Mention was made last year of the introduction of through carriage facilities between Aberdeen and Penzance, and during 1922 a number of other through services were inaugurated. Such developments were, in fact, a special feature of the year, though it is not necessary to consider this aspect in detail.

Of the new engines previously illustrated and described, little can be said in regard to performance, the North Eastern 4-6-2 and North Staffordshire 0-6-0 tank engines have been placed in service too recently; the electric locomotive illustrated in figure 6 is necessarily confined to private trial conditions; there are only one or two of the rebuilt engines shown in figure 5 yet completed; and there are only two Great Northern *Pacifics*. The writer is, therefore, able to describe, from personal experience, only the work of the Glasgow & South Western 4-6-4 tank engines, and to refer to a notable run with an exceptional load by one of the Great Northern 4-6-2 engines.

Dealing first with the latter performance, No. 1471 recently worked a test train consisting of 20 bogie vehicles, 610 tons behind the tender, from King's Cross to Grantham, 105.5 miles in 122 minutes. The start, through tunnels, is on gradients of about 1 in 105-110, and 7.5 minutes were taken to pass Finsbury Park, 2.5 miles. Potters Bar, 12.7 miles, largely on 1 in 200 adverse grades, was passed 16.5 minutes later. Easier and favourable sections beyond enabled the 46.2 miles to Huntingdon to be covered in 45 minutes. Peterborough, 17.5 miles further, was passed in 17 minutes, at the usual reduced speed, and in 86 minutes from King's Cross (76.4 miles) and 62 minutes from Potters Bar (63.7 miles). Thence is a nearly continuous climb to Stoke summit, 23.7 miles from Peterborough, passed in 30 minutes, and Grantham was reached, as stated, in 122 minutes from London, 105.5 miles. This schedule is representative of ordinary practice with heavier trains, though never with such a load, and is only improved upon by certain relatively light expresses. In ordinary practice, Nos. 1470 and 1471 have been working trains of about 450 and even 500 tons, the former load being now standard for the 5.40 p. m. Leeds express from King's Cross.

On the Glasgow & South Western Railway, Mr. Whitelegg's 4-6-4 tank engines have for some time worked regularly the 50-minute expresses between Glasgow and Ayr, 41.4 miles. The route, while not very severely graded, is com-

plicated by numerous junctions, and in the Glasgow district high speed cannot be made for the first few miles after leaving St. Enoch. Hence the allowance of 50 minutes calls for a high standard of performance. The engine was No. 541, of the 4-6-4 tank class, and the load seven bogie coaches and a restaurant car, a good 210 tons. Leaving punctually, easy running was the order for some distance, and Paisley (Gilmour Street) was passed at about 50 miles per hour (7.7 miles in 11.6 min.). Once clear of Paisley the running smartened considerably. The 3.2 miles to Johnstone occupied 4.1 minutes, 7.7 miles thence to Beith, 8.7 minutes, and Kilwinning was passed at about 65 miles per hour in 8.2 minutes from Beith (8.2 miles), and 21 minutes from Paisley (19.1 miles). Onwards to the old platform at Troon, 8.1 miles, occupied 7.8 minutes, speed reaching up to 65-70 miles per hour, and Prestwick (3.4 miles) was passed, still at high speed, in 3.3 minutes. At Newton-on-Ayr it became necessary to ease off and to whistle for signals, but that station was passed in 12.9 minutes from Kilwinning (13.4 miles); 33.9 minutes from Paisley (32.5 miles); and 45.5 minutes from St. Enoch (40.2 miles). Checks then brought us almost to a stand at the home signal outside Ayr station, in 47.4 minutes, but we stopped at the main platform in a few seconds over 49 minutes, still virtually a minute before time.

A trip behind an engine of the same class from St. Enoch to Kilmarnock may also be outlined, on the 10.45 p. m. night express for the south. No. 545 had a load of about 240 tons. As the route is very severely graded for much of the distance, this load was a good one, even for so powerful an engine. The first 16.7 miles to Dunlop include grades of 1 in 67, 69, 70 and 78, but were covered in 23.5 minutes. The summit just beyond Dunlop leads to the descent to Kilmarnock, but this is too steep to permit of excessive speed, and so, with intermediate brake application, the remaining 7.7 miles to Kilmarnock occupied 9 minutes.

When first placed in service one of these engines was officially tested on a main line journey between Glasgow and Carlisle, with two intermediate stops, thus overcoming the difficulty attending the use of a tank engine for a total journey of 115 1/2 miles each way. The load from Glasgow (St. Enoch) was 310 tons. No. 544 passed Dunlop, 16.7 miles, in 27.5 minutes, completing the remaining 7.7 miles downhill in 8.7 minutes. At Kilmarnock the load was increased to 340 tons. The long and almost continuous climb, partly at 1 in 100 or not much easier, to New Cumnock, 21.2 miles, was completed in 30.2 minutes; thence to Carronbridge, 19.4 miles, took 21 minutes, and the remaining 17.5 miles down to Dumfries, including a signal check, were run in 18.5 minutes. At Dumfries the load was further increased to 440 tons, the route being relatively much easier. Annan, 15.5 miles, was passed in 20.3 minutes, and the remaining 17.6 miles to Carlisle, including a long slow in, occupied 20.2 minutes.

Returning with 440 tons to Dumfries, No. 544 made the run of 33.1 miles from Carlisle in 41.5 minutes; with 325 tons completed the long climb of 36.9 miles from Dumfries to New Cumnock in 55 minutes, including a signal stop for 6 minutes. Thence down to Kilmarnock, 21.2 miles, and including a 3-minute signal stop, occuped 24.7 minutes. The complete run of 58.1 miles from Dumfries, including two signal stops aggregat-

ing 9 minutes, was thus made in 79.7 minutes. From Kilmarnock to Glasgow the load was 360 tons. Dunlop, all steep gradients, was passed in 15.5 minutes (7.7 miles), and the remaining 16.7 miles down to Glasgow in 21.1 minutes. These times were rather better than those ordinary scheduled, and the loads considerably more than those taken by the usual main line engines without pilot assistance .

In regard to work on other railways the writer's experiences during the period under review have been somewhat varied, including a number of runs on certain lines, in some instances on trains which are not usually timed, and on other lines, by force of circumstances, none at all of any special interest. Moreover, without any element of choice, a large proportion included four coupled engines, both 4-4-0 and 4-4-2, and in one case a 2-4-0.

Two double journeys by the London & North Western route between London and Carlisle may first be noted, these being given pride of place because of the heavy loads concerned, except in one case, and because of the diversity of locomotives employed. In the first case a superheater 4-4-0 No. 1680, *Loyalty* (1), had a load of 420 tons. The difficult 31.6 miles to Tring summit occupied 45.9 minutes, and the remaining 51 miles to Rugby 51.6 minutes. Starting again, the undulating and in places fairly difficult 51 miles to pass Stafford at reduced speed occupied 57 minutes, and the 24.5 miles thence to Crewe, about half on ascending gradients, and including a long and easy run in, were completed in 30.5 minutes.

The same load was taken on by a four-cylinder 4-6-0 engine of the *Claughton* class (1). The first stage from Crewe to Wigan, start to stop, was run in 45 minutes (35.8 miles), and the 15.2 miles thence to Preston in 22.3 minutes, both these sections being unsuitable for notably fast running. Lancaster (21 miles) was passed in 26 minutes, the gradients gradually becoming more difficult, and a stop was made at Oxenholme for pilot assistance in 52 minutes from Preston (40.1 miles). The very stiff climb to Shap Summit, of which the last 4 miles are at 1 in 75, with an old 2-4-0 engine assisting, was completed in 31 minutes (18.6 miles). At the summit a stop was made to detach the pilot engine, and the remaining 31.3 miles, generally favourable, were completed in 34.2 minutes.

A second journey over the same route was equally interesting, but perhaps somewhat less remarkable. The load was no less than 470 tons for a non-stop run of 158 miles from Euston to Crewe, booked in 175 minutes. Two engines were, however, supplied, a two-cylinder 4-6-0, No. 249 (2), and a 4-4-0, No. 2056, *Phaeton*. This combination naturally dealt with the heavy load easily, passing Tring summit (31.6 miles) in 38.5 minutes, and covering the 51 miles onwards to Rugby in exactly 51 minutes. Thence to Stafford (slack) the 51 miles occupied 55.3 minutes, and the remaining 24.5 miles to a check and stop outside Crewe, 27.5 minutes.

With the load reduced to 340 tons, a four-cylinder 4-6-0, No. 1694 (1) was assisted by an old 2-4-0 throughout to Carlisle. The first stage to Wigan (35.8 miles), start to stop, occupied a few seconds over 42 minutes.

(1) See *Bulletin of the International Railway Congress Association*, April 1914, and *Bulletin of the International Railway Association*, April 1921.

(2) See *Bulletin of the International Railway Congress Association*, April 1912.

Thence to Penrith (87.4 miles) no stop was made. Preston was passed slowly in 19.8 minutes (15.2 miles). Oxenholme was passed in 50 minutes from Preston (40.1 miles). Including a severe relaying slack at Tebay, just as an effort was being made in view of the Shap incline ahead, Shap summit was surmounted 33 minutes later (18.6 miles), and the run of 13.5 miles to Penrith was completed in 14 minutes. The final 17.8 miles to Carlisle included a check and therefore occupied 21.7 minutes.

In the opposite direction the first run was behind a forty-year old 2-4-0 engine No. 1678, *Airey*, but with a load of only 100 tons, through coaches from Stranraer being sent on separately from Carlisle to Crewe without waiting for the train to which they should have been attached. With this load, even over the difficult grades of part of the route, time was kept easily. Preston was passed in 111.4 minutes (90 miles), the remaining 51 miles to Crewe, including signal checks, occupying 67.4 minutes.

Attached to a Holyhead boat express at Crewe, a four-cylinder 4-6-0, No. 1097 (1), had a load of 380 tons, but as the schedule was somewhat easy no special importance attaches to the fact that the 60.9 miles to a stop at Nuneaton occupied 76.4 minutes; the 14.6 miles to Rugby, 22.4 minutes; 36.1 miles thence to Bletchley, 44.7 minutes; and 41.3 miles to Willesden Junction, 48.9 minutes, in each case start to stop.

The second journey involved a load of 450 tons from Carlisle to Preston, worked by a two-cylinder 4-6-0, No. 273 (2), assisted by a 4-4-0, No. 675. Shap summit (31.3 miles) was passed in 46.1 minutes. The fairly easy 37.7 miles to a stop at Lancaster were run in 40.1 minutes. Thence to Preston the 21 miles occupied 26.6 minutes. With the load reduced to 320 tons, the 4-6-0 engine alone covered the 51 miles to Crewe, including checks, in 63 minutes.

A four-cylinder 4-6-0, No. 42 (1), with 320 tons after leaving Rugby, was badly checked near Kilsby tunnel, but from Welton the 75.3 miles to Euston occupied only 82 minutes.

As a comparison to the foregoing record, a double journey between London and Edinburgh by the East Coast route, involving Great Northern and North Eastern locomotives, may now be described, though the loads were lighter (on the particular trains used) but single-headed throughout.

With a load of 330 tons a Great Northern 4-4-2, No. 279 (2), an engine rebuilt a few years ago as a four-cylinder experimental design, passed Potters Bar summit (12.7 miles) in 20.2 minutes. Thence to Hitchin (19.2 miles) occupied 21.8 minutes, and the next 27 miles to Huntingdon, 25.2 minutes. At Peterborough (passed slowly) the 76.2 miles had been covered in 89.9 minutes. Thence to Stoke summit (100 miles from London in 119.2 minutes) the climb of 23.7 miles was completed in 29.3 minutes, the arrival at Grantham being made in 126.7 minutes from London (105.5 miles), about 40 seconds over the booked time.

With the same load a superheater 4-4-2, No. 1447 (3), passed Newark (14.6 miles) in 16.7 minutes, ran the next 18.5

(1) See *Bulletin of the International Railway Congress Association*, April 1914, and *Bulletin of the International Railway Association*, April 1921.

(2) See *Bulletin of the International Railway Congress Association*, April 912.

(1) See *Bulletin of the International Railway Congress Association*, April 1914.

(2) See *Bulletin of the International Railway Association*, January-February-March 1920.

(3) See *Bulletin of the International Railway Congress Association*, April 1912.

miles to Retford in 20 minutes, and the succeeding 17.4 miles to Doncaster (slightly reduced speed) in 17.2 minutes. Selby (slack for swing bridge) was passed 20 minutes later (18.4 miles), and the remaining 13.8 miles to York, including delays, in 20.7 minutes.

A North Eastern three-cylinder 4-4-2, No. 719 (1), on a somewhat easy shedule, passed Darlington (44.1 miles) in 55.5 minutes from York, and Durham (22 miles) 26 minutes later. Thence to Newcastle, 14.5 miles occupied 17.1 minutes, the run of 80.7 miles from York having been completed in 100.6 minutes, rather better work being done over the harder section north of Darlington. than on the fairly easy 44.1 miles south thereof. A more recent engine of the same class, No. 2194 (1), but on a much harder route, passed Alnmouth in 46.5 minutes (34.8 miles), and Berwick (reduced speed) 36.9 minutes later (32.1 miles). Onwards the gradients become very severe, the 16.2 miles to Grant's House requiring 22.6 minutes, and the remaining 41.5 miles to Edinburgh (Waverley) were covered in 46.5 minutes.

Returning from Edinburgh, a North Eastern 4-6-0, No. 784, with 250 tons, passed Dunbar, 29.5 miles in 35.4 minutes, and completed the climb to Cockburnspath summit, 12 miles, in 17.9 minutes. Thence to Berwick, the 16.2 miles were run in 21.1 minutes. Passing the border station at reduced speed, the 32.1 miles to Alnmouth occupied 38 minutes; thence to Morpeth, 18.2 miles were covered in 20 minutes, and the remaining 16.6 miles to Newcastle, including slow running for the last few miles, were completed in 25.8 minutes. Continuing south behind three-cylinder 4-4-2 engine, No. 2194, mentioned above, Durham (14.5 miles) was passed in 20.5 minutes; thence to Darlington (22 miles) occupied 31.5 minutes, this section being taken very easily, while intermediately gradients are severe, and the 44.1 miles onwards to York occupied 51.5 minutes, the schedule of this train being fairly liberal.

Great Northern Railway superheater 4-4-2, No. 1452 (1) passed Selby, 13.8 miles, in 19 minutes, and completed the 18.4 miles to a stop at Doncaster in 22.3 minutes. Starting again, Retford was passed in 20.4 minutes (17.4 miles), and Newark, with an intermediate check (18.5 miles) 21.2 minutes later. The 14.6 miles thence to Grantham (passed at reduced speed) occupied 18.5 minutes, the route being difficult, and Stoke Box, the summit, was passed 11.1 minutes later. Thence to a stop at Peterborough the 23.7 miles were run in 24 minutes. A small 4-4-2, No. 989, continued to London, passing Huntingdon, 17.3 miles in 23.5 minutes; thence to Hitchin, 27 miles, occupied 29.6 minutes; Potters Bar was passed 22.7 minutes later (19.2 miles), most of the route so far being moderately difficult in this direction. The final run of 12.7 miles into King's Cross, with the usual careful descent of the incline from Finsbury Park, occupied 13.7 minutes.

Before leaving these Anglo-Scottish trains, a few journeys associated with but not necessarily in continuation of them, behind locomotives belonging to the Scottish railways, may be briefly outlined.

On the Caledonian Railway all runs mentioned were behind superheater 4-4-0's of Mr. McIntosh's last or of Mr. W. Pickersgill's design, though only sections are included, other portions of the respective journeys not being suitable for

(1) See *Bulletin of the International Railway Congress Association*, April 1912.

(1) See *Bulletin of the International Railway Congress Association*, April 1912.

high speed schedules. Nos. 73 and 137 (1), working a load of 380 tons, covered the 39.7 miles from Carlisle to Beattock in the fine time of 42 minutes, continuing to Beattock summit, 10 miles at 1 in 88, 80 and 75, where a stop was made for water, in 19.3 minutes. Thence to Carstairs, mainly easy, 23.8 miles were run in 26.3 minutes, and, including a check, the next 8.9 miles to a signal stop approaching Law Junction occupied 10.8 minutes. A second run over this route involved Nos. 122 and 72, of the same class, with a load of 300 tons, running to Carstairs from Carlisle without a stop at either Beattock or Beattock summit. Beattock was passed in 47.5 minutes, the summit being passed 18.5 minutes later. Thence to a stop at Carstairs the 23.8 miles were covered in 28.5 minutes.

In the opposite direction, No. 88, with 360 tons, covered the steep 17.2 miles from Symington to Beattock summit in 28.1 minutes, and then, with one check, completed the run of 49.7 miles to Carlisle in 55.1 minutes, though not all of the route is easy and the very steep portions necessitate frequent brake applications. With a load officially stated as 441 tons, a single Caledonian 4-4-0, No. 72, essayed the task of working this unaided from Symington to Carlisle. Unfortunately, the difficult stage of 17.2 miles to Beattock summit was hampered by signal delays and further complicated by the fact that the brakes of one vehicle had « stuck on » and would not release for some time, so that 39.7 minutes were required for this stage. Thence to Beattock, down the bank, the 10 miles were run in 11.4 minutes, and the undulating 39.7 miles thence to Carlisle were run in the very fine time of 43.2 minutes.

On the North British Railway all runs to be referred to were made behind 4-4-2 engines now superheated (1). On this line there are few very fast times (on paper), but in view of the numerous curves, and the frequent gradients, in some cases both lengthy and steep, the work with heavy loads, which only is considered, is distinctly meritorious.

On the terrifically graded « Waverley » route between Edinburgh and Carlisle, with 280 tons, No. 879, *Abbotsford*, accelerated very rapidly on the short descent out of Edinburgh. Then follows an almost continuous climb of 15 miles from Portobello to Falahill summit, at 1 in 80, 100, and 175 to 250 for 6 miles, the remaining 9 being virtually unbroken at 1 in 70. This stage occupied 29.7 minutes, the lowest speed being 25 miles per hour. Thence down to the first stop, at Galashiels, with frequent brake applications on the steep grades, the 15.5 miles were run in 17.5 minutes. Little interest attaches to the section from Galashiels to Hawick. Thence, however, is an almost continuous climb to Whitrope summit, almost 11 miles, nearly all at 1 in 72 to 80 and 96, except for two or three short sections at about 1 in 120, and this occupied 26 minutes, lowest speed 25 miles per hour. A short spurt preceded the slack for Riccarton curves. Thence to Carlisle is generally easy, except for frequent brake applications on the steep down grades, the remaining 32.3 miles to Carlisle occupying 39.2 minutes, with the usual slow run in.

In the opposite direction, with 280 tons, No. 878, *Hazeldean*, covered the

(1) See *Bulletin of the International Railway Congress Association*, April 1911, and *Bulletin of the International Railway Association*, January-February-March 1920.

(1) See *Bulletin of the International Railway Association*, January-February-March 1920.

undulating or moderately difficult 24.2 miles from Carlisle to Newcastleton in 31.7 minutes, and then climbed the 8.3 miles to Riccarton Junction, almost continuously at 1 in 75, in 17.3 minutes. The remaining 2 miles to the actual summit proved somewhat difficult, owing to slipping on greasy rails, but once through the summit tunnel the distance of nearly 11 miles down to Hawick was run, with steadying brake applications, in 13.3 minutes. Omitting the section from Hawick to Galashiels, the 15.3 miles of continuous climbing to Falahill summit occupied 24.8 minutes, and the final run of 18 miles into Edinburgh (Waverley) were run steadily in 22 minutes.

North of Edinburgh, too, gradients are far from easy, with frequent sections at 1 in 90-120, but there are, in addition, numerous curves and junctions every few miles, calling for reduced speed, so that sensational times are impossible. Loads, too, are nearly always considerable on the Edinburgh-Aberdeen trains. Several runs could be referred to, but space cannot be spared for the lengthy explanations necessary to enable the actual quality of the work involved to be appreciated.

On the Glasgow & South Western Railway, a rebuilt 4-6-0 engine, No. 510 (1), with 240 tons, ran from Carlisle to Annan, 17.6 miles, in 26.7 minutes, and thence to Dumfries, 15.5 miles, in 22.1 minutes, in both cases start to stop. An old 4-4-0 engine was then attached as pilot to New Cumnock, an almost continuous climb of 36.9 miles, run in 46.6 minutes. After detaching the pilot, with an intermediate tunnel repair check, the 21.2 miles down to Kilmarnock were run in 27 minutes. Unaided, No. 510 covered the very steeply graded section of 7.7 miles to Dunlop, including gradients of 1 in 87 and 75, in 17.6 minutes, and completed the run of 16.7 miles into the Glasgow terminus in 20.9 minutes.

Over the same route, No. 327, a 4-4-0 with 6 foot wheels (1), built originally for the Greenock line, with a load of 200 tons, covered the 17.6 miles from Carlisle to Annan in 24.6 minutes, start to stop, and thence to Dumfries, 15.5 miles, in 18.7 minutes. From Dumfries to New Cumnock, without assistance, the 36.9 miles occupied 48.5 minutes. The run of 21.2 miles down to Kilmarnock was covered in 24.5 minutes.

In the opposite direction, a 4-6-0, No. 501 (2), with 190 tons, occupied 22.9 minutes to pass Lugton, 14.4 miles from Glasgow almost entirely on adverse grades and with sections as steep as 1 in 69 and 70. Most of the 10 miles thence to Kilmarnock are downhill, and were covered in 12.7 minutes. With the same load, No. 486 of the same class covered the fairly difficult 21.2 miles to New Cumnock in 33.2 minutes. The long run down to Dumfries (36.9 miles) was completed in 41.3 minutes, the latter station being passed slowly. The remainder of the journey had to be taken easily, signals being whistled down several times, while at Gretna an actual stop had to be made. Annan was passed in 20 minutes from Dumfries (15.5 miles), delays thence to Carlisle causing the remaining 17.7 miles to occupy 29 minutes.

Brief reference may also be made to a run with the Ayr non-stop, leaving St. Enoch at 5.10 p. m., booked to run the 41.4 miles in 50 minutes, compared

(1) See *Bulletin of the International Railway Association*, April 1921

(1) See *Bulletin of the International Railway Congress Association*, April 1914.

(2) See *Bulletin of the International Railway Association*, April 1921.

with that behind 4-6-4 tank engine, No. 541, previously described. The load was 230 tons, taken by one of Mr. Whitelegg's rebuilt 4-4-0's, No. 370. Paisley (Gilmour Street) was passed in 12.4 minutes (7.7 miles), and Elderslie in 15.2 minutes (9.7 miles). The 13.6 miles from Elderslie to Dalry were covered in 15.6. Thence to Irvine, the 6.9 miles were run in 6.7 minutes, and the remaining 11.2 miles to the stop at Ayr in 12 minutes, thus completing the journey from Glasgow in 49.5 minutes.

On the London & South Western Railway principal interest attaches to the chief West of England expresses giving start to stop runs of 83.8 miles between Waterloo and Salisbury, and of 88 miles between Salisbury and Exeter. Both are scheduled very tightly, the former rather the faster in that it includes long adverse gradients of moderate severity, calling for hard steady work, rather than the ascent of very steep inclines. The latter, however, is steeply undulating, with several sections of 1 in 80-100-120-130-140 and a long climb of 1 in 70-80 continuously for several miles. With a load of 330 tons, one of Mr. Urie's large 4-6-0 superheater locomotives, with 6 ft. 7 in. coupled wheels and 20 by 28 inch cylinders, No. 740 (1), passed Woking, 24.4 miles, in 29.9 minutes, and covered the next 23.5 miles to Basingstoke in 25.7 minutes, thus occupying 55.6 minutes for 47.9 miles, mostly on rising though not steep gradients, and including only one or two fairly short favourable sections. Thence to Andover, 18.5 miles, occupied 19.6 minutes, so that 66.4 miles had been run in 75.2 minutes. Onwards is a steeply graded section, followed by a long incline down to Salisbury, the remaining 17.4 miles occupying 20.1 minutes, with a maximum speed of about 75 miles per hour, and completing the non-stop journey of 83.8 miles from Waterloo in 95.4 minutes, within a few seconds of schedule.

The same engine, with load unaltered, continued to Exeter, starting 2 minutes late and arriving 1 1/2 minutes behind time, the allowance being 104 minutes for 88 miles of difficult route. The first 28.4 miles occupied 33.8 minutes, and at Axminster, virtually the foot of the hardest section, but including intermediate difficulties, 61 miles had been run in 68.1 minutes. The ascent of Colyton bank, 1 in 70-80 for 7.7 miles, was complicated by two permanent way slacks, and occupied 14.1 minutes to the summit. Thence to Exeter, downhill for most of the way (maximum speed kept down to about 75 miles per hour), 19.3 miles were covered in 21 minutes to the stop.

On the return journey a rebuilt superheater 4-4-0 engine, with 6 ft. 7 in. coupled wheels, gave some very fine times between Exeter and Waterloo, though including several stops. The load was 270 tons, quite sufficient for a relatively small engine over a route far from easy. From Exeter to Honiton tunnel, 19.3 miles, mainly on ascending grades, largely at 1 in 120 or 140, occupied the very fine time of 27.2 minutes. From the summit to a stop at Axminster, the 7.7 miles took 8.5 minutes, though this is mainly downhill. The steeply undulating 21.9 miles to Yeovil Junction occupied 27.3 minutes start to stop. Thence to Gillingham, the 17.4 miles took 29 minutes, while the 21.7 miles to Salisbury were run in 31 minutes, both stages being start to stop and involving some adverse gradients intermediately. With the load unaltered, the same engine

(1) See *Bulletin of the International Railway Association*, January-February-March 1920.

ran to Andover start to stop, largely on severe ascending gradients, in 27.5 minutes (17.4 miles), and then ran from Andover to a stop outside Waterloo (London), 66.2 miles in 73 minutes. Intermediate sections included 18.5 miles in 24 minutes, 23.5 miles in 22 minutes, and 24.2 miles (with a permanent way repair slack) in 27 minutes, though on the whole the gradients were favourable.

The Great Central Railway is notable for the very fast timing of trains which make a number of intermediate stops. Loads are moderately heavy, especially when 4-4-0 engines are used, and in view of the frequency of the usual grades of 1 in 176, in both directions, even the 4-6-0 locomotives have their work cut out to keep time. On a special trip, a four-cylinder 4-6-0, No. 1166, *Earl Haig* (1) (Field Marshal Earl Haig himself was a passenger in the Directors' saloon attached), with a heavier load than usual, 250 tons, after traversing the London area at the ordinary moderate speeds, the first 11.6 miles occupying 18.6 minutes, covered the remaining 16.3 miles to a stop at High Wycombe, a fairly difficult route, in 19 minutes. Thence to the next stop at Woodford, 45.7 miles, also with difficult sections, were run in 48.7 minutes. The next 14.1 miles to Rugby occupied 16.5 minutes, and the 19.9 miles to Leicester, 21.8 minutes, in both cases start to stop. Continuing, the 23.4 miles to Nottingham were run in 26.2 minutes, and the 38.2 miles onwards to Sheffield, where adverse gradients abound and high speed is not practicable, owing to the numerous junctions and colliery sidings, occupied 50.1 minutes.

Returning, a superheater 4-4-0, No. 508, *Prince of Wales* (1), had the heavy load of 280 tons. From Sheffield to Nottingham, 38.2 miles, occupied 49.3 minutes. Thence the following start to stop times on various stages were : 13.6 miles in 17.1 minutes; 9.8 miles in 13.6 minutes; 19.9 miles (mainly uphill) in 24.8 minutes; 14.1 miles in 18.2 minutes; and 45.7 miles in 47.9 minutes. From High Wycombe to passing Northolt Junction, beyond which point speed is necessarily relatively slow, 16.3 miles were run in 18.6 minutes, the remaining 11.6 miles occupying 16.1 minutes. This journey, in view of the heavy load, is especially meritorious, as the route is far from easy on any section.

On the Great Eastern Railway steep gradients are frequent, and there are several places where reduced speed is necessary, so that notably high average speeds, with the usual considerable loads, are rarely practicable. Moreover, during the summer traffic, especially on a Saturday, it is rarely possible to get an unchecked journey. On the first part of the 12.25 p. m. train, non-stop from Liverpool Street to North Walsham, 130.2 miles, a 4-6-0, No. 1570 (2), with 330 tons, was so seriously delayed by signals that the 19.3 miles to Ingrave summit, usually a testing run, occupied 35 minutes. Thence, with two intermediate checks and two ordinary speed orders, the 49.4 miles to Ipswich occupied 61.8 minutes. Thence to Trowse the 45.1 miles occupied 52.3 minutes. The remainder of the journey involves curve slacks and very steep gradients, so that it possesses no special interest unless described in extended detail.

A superheater 4-4-0 engine, No. 1849,

(1) See *Bulletin of the International Railway Association*, January-February-March 1920 and April 1921.

(1) See *Bulletin of the International Railway Association*, April 1914 and April 1921.

(2) See *Bulletin of the International Railway Association*, April 1921.

with 240 tons, after an initial delay, and one intermediate check on the steepest part, passed Ingrave summit in 33.8 minutes (19.3 miles); passed Chelmsford, 10.3 miles, 11 minutes later; occupied 23.7 minutes for the 22 miles to Colchester, and 21.4 minutes to Ipswich, 17 miles of moderate difficulty.

In the opposite direction several good runs may be briefly reviewed : 4-6-0, No. 1541, with 240 tons, passed Colchester in 24.1 minutes from Ipswich (17 miles, hard), Chelmsford 25.9 minutes later (22 miles), thence to Ingrave summit (10.4 miles) occupied 13.8 minutes, and the remaining 19.3 miles into Liverpool Street, with usual delays in the London area, 26.3 minutes. A similar engine, with 270 tons, passed Colchester in 22.9 minutes from Ipswich (17 miles), passed Chelmsford 28.6 minutes later (22 miles), surmounted Ingrave summit in 14.2 minutes (10.4 miles), and ran down to a signal stop outside Liverpool Street, 19.1 miles, in 24.8 minutes.

On the Cambridge main line principal interest attaches to a novel train instituted last summer from St. Pancras to Hunstanton, calling only at Cambridge and King's Lynn. A 4-6-0, No. 1557, with 190 tons, starting over a difficult local route to Tottenham, after passing Tottenham covered the 11 miles to Broxbourne in 13.2 minutes, the 13.3 miles to Bishops Stortford (reduced speed) in 13.9 minutes, 11.3 miles to Audley End in 14.1 minutes, and the remaining 14 miles to Cambridge in 17.8 minutes, so that the 49.7 miles from passing Tottenham had been run in the notable time, for this route, of 61 minutes. A mixed-traffic 2-4-0, with 5 ft. 8 in. coupled wheels, continued to King's Lynn, passing Ely (14.8 miles) in 19.2 minutes from Cambridge, and reaching King's Lynn (26.5 miles), 33.4 minutes later.

Between Cambridge and Liverpool Street 4-4-0, No. 1840, with 320 tons, covered the 25.3 miles to a stop at Bishops Stortford in 36.2 minutes, though the route is a hard one, and passed Tottenham, 24.3 miles further, in 28.8 minutes. 4-6-0, No. 1527, with the same load, covered the same stages in 35.2 and 29.2 minutes. These times are distinctly good, as the route is one which is not usually regarded as productive of notable times, while the loads are nearly always considerable.

The foregoing remarks, though they do not cover all the principal lines, and, in some cases, the fastest schedules are not concerned, by force of circumstances, will indicate the general character of the locomotive work now performed on British railways, usually with heavy loads, and frequently under conditions which render the work done far more notable than the mere statement of average speeds and scheduled times would suggest.

[625 .216 (.54)]

Automatic mechanical couplers for the Indian (broad gauge) Railways,

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Figs. 1 to 3, pp. 225 and 227.

The proposal to substitute a stronger and more efficient form of coupler for the present buffers and couplings has been before the Government of India for some fifteen years past, and considerable investigation has been made as to how such a reform can be carried out. It is common knowledge that the New South Wales Government Railways are making a change from buffers and slack three link couplings to mechanical couplers similar to those in use on the American railways. A deputation sent by the Indian Railway Board to Australia to look into this procedure having reported very favourably from the traffic point of view, the authority mentioned is now engaged on a thorough investigation of the whole subject and an Officer has been sent to the United States to secure further information.

The pioneer Administration in this effort to secure a radical change in coupling arrangements has been the Great Indian Peninsula Railway, which, due to its geographical position, has to handle perhaps the heaviest trains in India over lines abounding in heavy grades. The troubles arising from the use of screw couplings have convinced those in authority, for a considerable period past, that a stronger, more efficient and more easily operated device is necessary if traffic is to be satisfactorily handled on modern lines.

Briefly the scheme now put forward is to attach mechanical couplers, of a form or type to be decided on, below the underframe of the present vehicles in a self-contained « draft » box or fitting which will enable the mechanical couplers to be used on adjacent vehicles, when fitted, without interfering with those which have only the ordinary coupling arrangements, and which will have to be coupled with them for a certain time during the transition period. (See figs. 1 and 2.)

The primary reasons dictating such a change as that outlined are, first, the requirement of something stronger than the present couplings and secondly, a quicker and more expeditious means of attaching and detaching the vehicles of the long trains now in service. Dealing with the first, comparative strength — the present screw couplings if made of best Yorkshire iron have a breaking strain of about 40 tons, whilst if made of high-tensile steel will stand a destruction test of 80 tons. Nickel-chrome may possibly secure 100 tons, but there are objections against the employment of these alloys for couplings and draft gear. They require very careful treatment if they are to be relied upon and service shows that they deteriorate from the shocks administered in traffic. Further there are difficulties in repair when required, so that really the high-tensile steel coupling of 80 odd tons is considered the

Fig. 1. — Showing two wagons coupled with screw-couplings one wagon fitted with M. C. B. couplers.

Fig. 2. — Indian shunter operating M. C. B. coupler placed below the present draw gear.

most promising at present. In most mechanical arrangements a margin of safety of 5 to 1 is required, so that a coupling possessing a breaking strain limit of 80 odd tons should only be used for strains up to say 16 tons — a figure which must of necessity be frequently exceeded when it is remembered that engines are in use that have a tractive effort above this and certainly can administer shocks up to four or five times that figure. The proof of this statement is exemplified by the number of high-tensile couplings broken in traffic. It must be conceded that if the couplings were always properly screwed up tight, there would be less risk in this direction, but in actual practice they are *not properly screwed up*, nor can they possibly be tightened to the extent desired, unless an engine is present to close up the train; no ordinary individual can pull a number of vehicles together by turning the lever of a screw-coupling. The state of affairs produced by slack screw-couplings is aggravated by the introduction of continuous brakes, and it is not difficult to imagine the severe shocks administered throughout a long goods train of loosely coupled vehicles. The differences in the adjustment of the brake gear, etc., on the different vehicles must of necessity produce strains when the brakes are applied in excess of what the couplings are intended to withstand.

The obvious remedy to this state of affairs is the adoption of some much stronger device and which will give practically a close coupling on impact, without the necessity of any manual effort; this is practically the proposal now put forward in recommending that a mechanical coupler should replace the screw-couplings and buffers at present in use.

The second reason for something being done in this direction is the delay and loss of time in manipulating trains due to the operation of screw couplings. Considerable capital outlay has been incurred in providing hump yards, gravity sidings, etc., to facilitate and quicken the marshalling of trains and so expedite transport. In England where the loose three-link coupling is used the shunter or man operating the sidings can instantaneously detach the links from the hooks by the extraneous use of a shunting pole over the buffers, but this cannot be done in Indian shunting yards with the attachments in use. The screw coupling must first be slackened and most of the manœuvring of the vehicles performed whilst the couplings are in this condition with the result that hundreds are broken during the operations. With a satisfactory arrangement of mechanical couplers, the wagons would be instantaneously coupled and uncoupling would be as expeditiously performed by simply operating the handles at the sides of the wagons; this would be a vast improvement on the present methods wherein it is essential that the shunter must go between each vehicle and loosen or tighten the screw coupling before movement can be made. Hence delays to transport and the second good reason for a change.

In the direction of economy, there is much to be said for a central mechanical coupler. Each vehicle will only require two draft arrangements against the six at present installed. The first cost of the four buffers, two draw gears and couplings in ordinary wagons is now in the neighbourhood of £80 whilst two couplers with their attendant gear can be procured for £40.

In dead weight there is again a saving as follows :

Four buffers, two draw-gears and couplings weigh 15 cwts. whilst

Fig. 3. — Two standard 20 ton wagons coupled together with M. C. B. couplers arranged as proposed by the Great Indian Peninsula Railway. If these wagons run as a pair during transition period cost of charge will be considerably reduced.

Two mechanical couplers weigh 10 cwts. giving a saving in tare of 5 cwts. per vehicle.

It is estimated that to carry out such a change on the broad gauge railways of India means the equipment of 5 000 locomotives, 20 000 carriages and 100 000 wagons with mechanical couplers, being say 75 % of the stock running, the remaining 25 % will probably be scrapped before a change could be completed. The cost of such a proceeding taking an average of 600 roupies per vehicle amounts to a round figure of 5 million sterling (£5 000 000) but it is estimated that nearly 1 million pounds sterling (£1 000 000) will be realized from the sale of buffers, couplings and scrap removed. As it is estimated that quite 1 million (£1 000 000) sterling is being spent annually on replacements, renewals and repairs to damaged couplings and buffers, it is anticipated a very considerable economy will be secured to revenue by the change, more than sufficient to pay a handsome return on the capital involved.

To sum up, the following advantages are expected to be derived from the introduction of mechanical couplers :

1° A much stronger attachment enabling heavier trains to be handled. It is the desire of the broad gauge Indian railways to eventually work up to a 3 000-5 000 ton train. The present screw couplings fail by hundreds with trains of 1 400-1 500 tons;

2° Securing a practically tight coupling *on impact* — a condition not attainable at present with the screw couplings *with goods trains.* The great majority of these are simply coupled and left to run owing to the unreliability of the Indian shunting staff; such a condition is intolerable *with continuous brakes in operation;*

3° A saving in tare weight of each ve-

hicle as only *two* couplers and buffing devices are required against *six* in the present type, namely four buffers and two draw-bars with couplings;

4° Increased speed of operation. From experiments made, the *quickest* time in which a screw coupling can be tightened up is about thirty seconds which means twenty-five minutes on a 50 wagon train, leaving out the time occupied by men traversing the length of the vehicles (with couplings in ordinary working condition it takes nearly double this). In the case of mechanical couplers, this is reduced to practically « nil ». The time occupied by the man passing along the vehicles to attach or detach brake pipes, etc., remains the same in either case;

5° Less resistance to the trains when traversing curves owing to the limitations in movement imposed by the side buffers when couplings are screwed up tight. Side buffers with springs of sufficient resistance for the heavy blows now administered offer a very serious increase to traction;

6° An enormous saving to revenue owing to the great reduction in repairs and renewals which a stronger mechanical attachment would ensure. The present cost for damaged screw couplings, draw-gear, buffers, etc., is estimated to amount to about *£1 000 000 per annum.*

It has been demonstrated that it is essential that any coupler to be satisfactory in service, should be devoid of links, shackles, pins, etc., liable to distortion — otherwise in operating the heavy trains anticipated, complications are sure to ensue, hence the preference to those couplers operating in the vertical plane as compared to any offered with hooks, etc., in the horizontal.

So far the enormous application of the so-called M. C. B. coupler, the standard in use on American railways, justified the expectation that some arrangement of this or a similar coupler will meet Indian requirements if it could be satisfactorily applied to existing stock. This possibility has been the subject of a large number of experiments and investigations by the Great Indian Peninsula Railway Administration and its Officers appear to be quite confident the change can be easily made and with a minimum of expense. This latter can be modified considerably if the traffic department will agree to a system of working vehicles in pairs or specially marshalled for a short period during transition.

[621 .132.8 (.485)]

The Ljungström turbine locomotive for the Swedish State Railways.

Figs. 1 to 13, pp. 230 to 239.

The steam locomotive has undergone many improvements since it first made its appearance, and is now built to develop powers considerably greater than even a few years ago. Nevertheless, the locomotive of to-day remains essentially of the same type as originally constructed, the steam driving a reciprocating engine exhausting to the atmosphere. This form of construction has become so standardised that it would seem almost rash to seek a solution of the problem based upon other principles, conservatism being justified by the simplicity, reliability and suitability for its purpose which the modern locomotive displays. But although these fundamental qualities explain the retention of the reciprocating engine, it must be recognised that the efficiency which has been reached by successive improvements is still only moderate. With compound engines using superheated steam and provided with feed-water heaters, one indicated horse-power can be obtained at present for the consumption of 2.42 lb. of coal per hour which corresponds to an overall thermodynamic efficiency of about 8 %. Although such a result may be ramarkable for a locomotive, it is very far from what is possible in the case of stationary steam plant. This comparatively low efficiency is due very largely to the limitations under which the locomotive builder labours, both as regards weight and available space. Lack of room for the cylinders has caused compounding to be abandoned for the most powerful engines, and the same reason renders the full expansion of the steam in a condensing engine practically out of the question. Feed water heaters provide a means of utilising a portion of the exhaust steam, the employement of waste gases for heating the feedwater being inadmissible on account of the size of the economiser required. Thus the modern locomotive permits not only the products of combustion to escape into the atmosphere at a high temperature, but also from 80 to 85 % of the exhaust steam.

Condensation of the steam with the economy which this permits of, becomes possible if a steam turbine is used and a high ratio of expansion can be attained with a relatively small amount of apparatus. Several attempts have been made to enable the locomotive to take advantage of this kind of motor, which has taken so prominent a place in power station and marine practice. Besides the ordinary problems underlying the construction of the turbine and its auxiliary apparatus there are others peculiar to its use on locomotives. Firstly, it is necessary to devise a satisfactory method of transmission of power from a high speed motor to the locomotive driving wheels, and secondly, there is the question of reversing the locomotive. The first difficulty is also met with in electric locomotives, although in this case the necessary speed-reduction is less, and the number of the solutions which have been suggested tend to shew that it is not more easy to utilise the rotation of a high speed shaft to drive the wheels than it is to use the reciprocatory motion of a piston.

These various problems appear to have been successfully solved in the locomo-

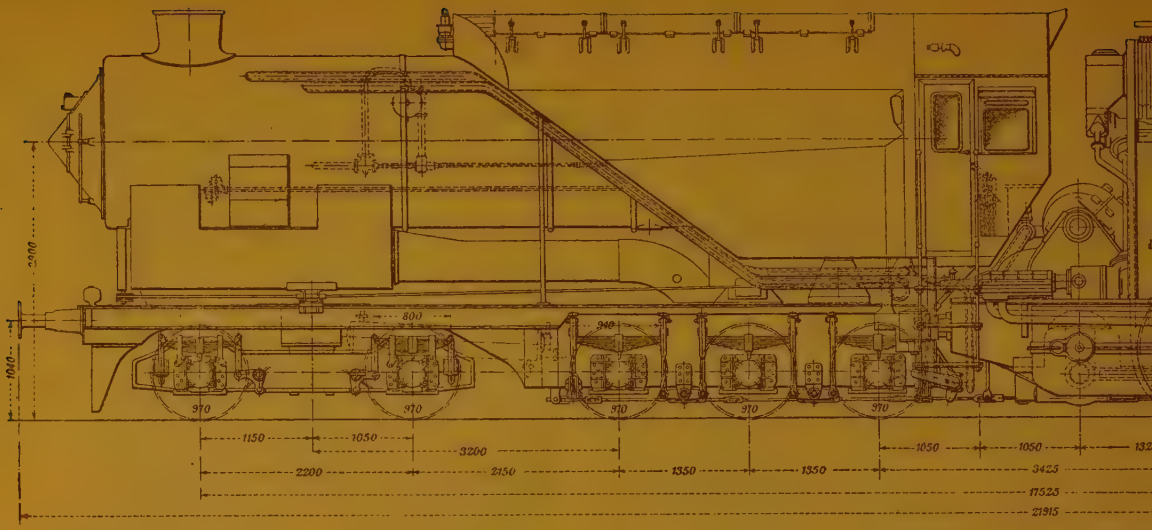


Fig. 1.

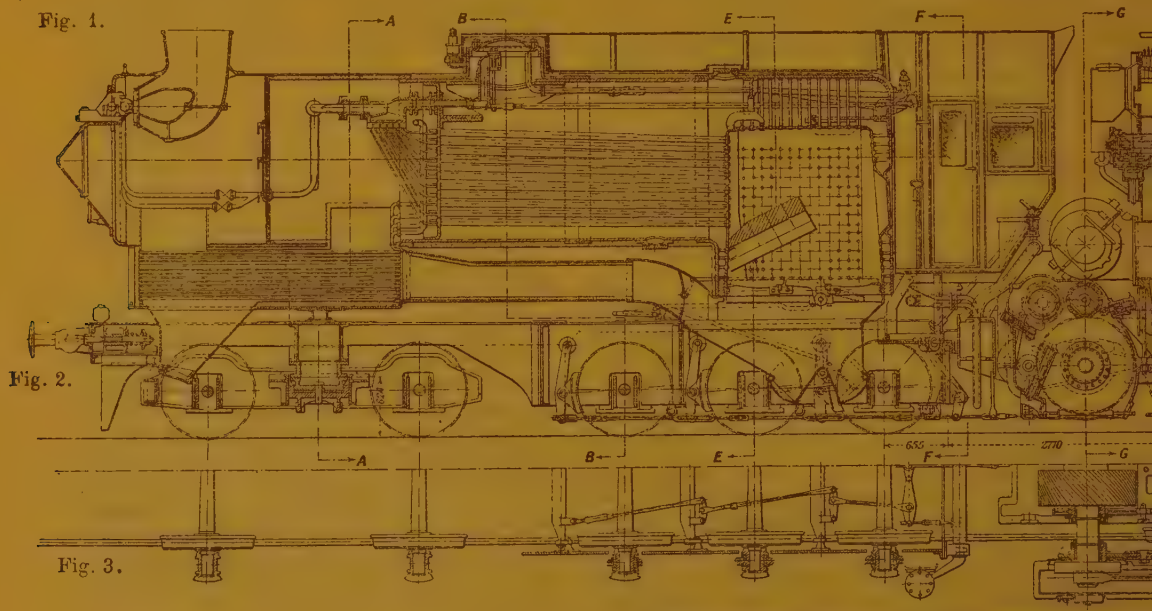


Fig. 2.

Fig. 3.

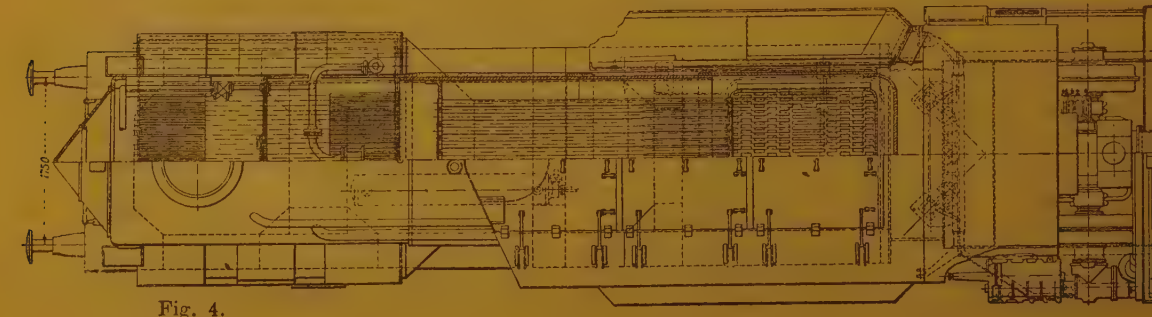
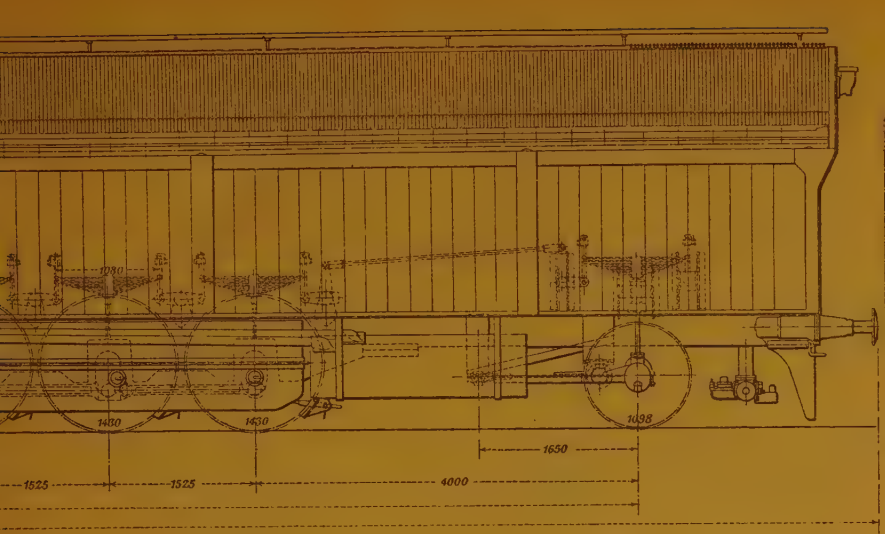


Fig. 4.

Figs. 1 to 7. — Ljungström



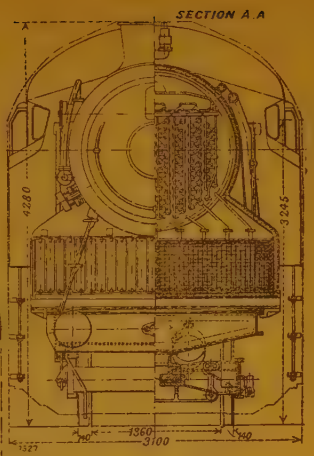
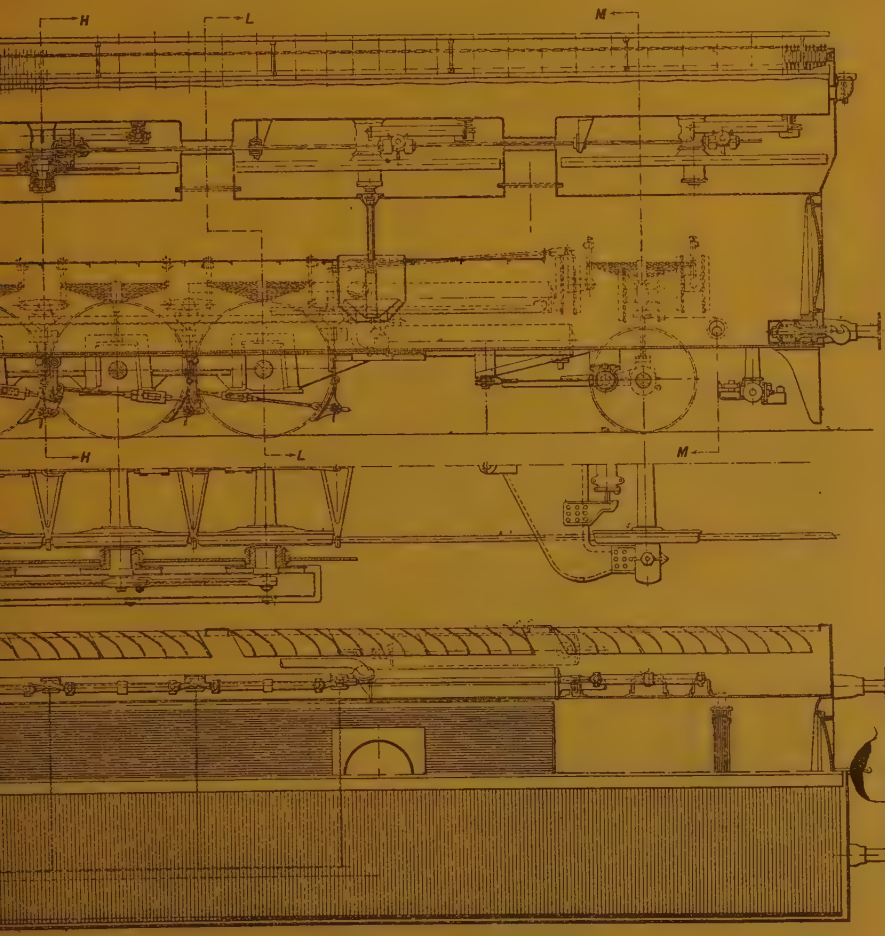


Fig. 5.



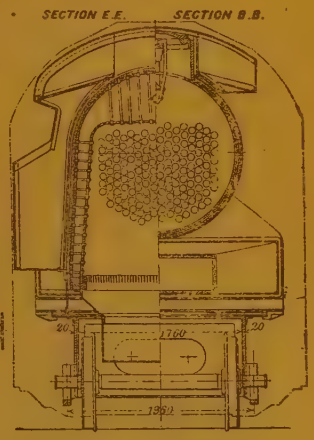


Fig. 6.

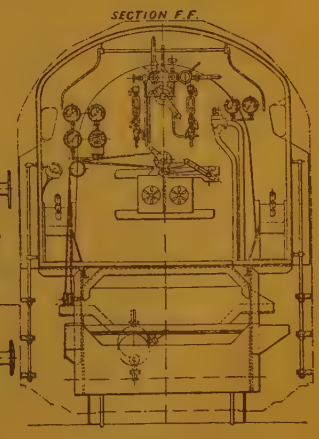


Fig. 7.

locomotive. — General arrangement.

tive built by the Aktiebolaget Ljungstroms Angturbin of Stockholm for the Swedish State Railways, which, although regarded as an experimental machine, has been constructed to develop a power equal to that of the most recent locomotives of the Swedish State. From a description of the Ljungstrom locomotive which has appeared in *Engineering* we present the following summary of a machine which is exceptional in many respects, and which marks a great departure from accepted locomotive practice.

The inventors of the locomotive, who are experienced turbine builders, have embodied in their design all those features which are necessary to secure the greatest possible efficiency, namely, a condensing steam turbine working with high pressure steam (300 lb: per square inch), and high superheat, as well as the heating both of the feed-water and of the air entering the firebox.

In its general appearance the Ljungstrom locomotive (figs. 1 to 7) resembles the ordinary type, but the front part which carries the boiler has no driving wheels, but is pushed by the hinder portion on which the turbine is mounted. The latter portion also carries the transmission gear, the condenser, and various auxiliary apparatus. The turbine, which develops 1 800 H. P. is connected to the three driving axles by means of double reduction gear. The condenser car weighs 64 tons in running order, 48 tons of which are carried on the driving wheels. A tractive effort of 12 tons can be attained, and the weight of the whole machine in running order is 126 tons.

The coal bunker takes the form of a saddle tank over the firebox, and holds 7 tons of coal. Coal descends from each side to two openings arranged one on each side of the firebox door, so that firing is rendered as convenient as possible.

In addition to the boiler, the front vehicle carries the air preheater. The condensate from the main turbine is returned to be boiler by a centrifugal pump driven by an auxiliary turbine, and passes successively through three heaters in series, each of which uses exhaust steam at a different temperature, coming from various auxiliary apparatus.

The air for combustion is heated by passing through tubes placed in the lower part of the smoke box. The air entering the tubles is controlled by moveable shutters, and after leaving them is conducted to the ashpan by a sheet iron duct. The air heater tubes are heated externally by the hot gases after the latter have passed the superheater. The incoming air is thus raised to a temperature of 300° Fahr. at the expense of the waste heat of the flue gases. The temperature of the latter is thereby lowered and their volume reduced, so that arrangements for producing a draught are simplified. This is effected by means of a small fan placed on the top of the smoke box and driven by a steam turbine.

The driving mechanism.

The turbine, illustrated in figure 8, is of the impulse-reaction type with axial flow of the steam. It develops 1 800 B.H.P. at a speed of 9 200 revolutions per minute, which corresponds to a speed of 68.75 miles per hour for the locomotive. It is situated crosswise at the back of the foot-plate. As the turbine is carried on the condenser car, while the boiler is carried on the front vehicle, it is necessary that the steam pipe should be flexible. This pipe is of steel, and the requisite flexibility is obtained by making it U-shaped. It should be mentioned in this connection that the special form of coupling between the vehicles limits their relative motion to a very small amount.

The steam enters a cast steel steam-chest and passes into the turbine through five nozzles independently controlled by oil pressure. It acts first upon an im-

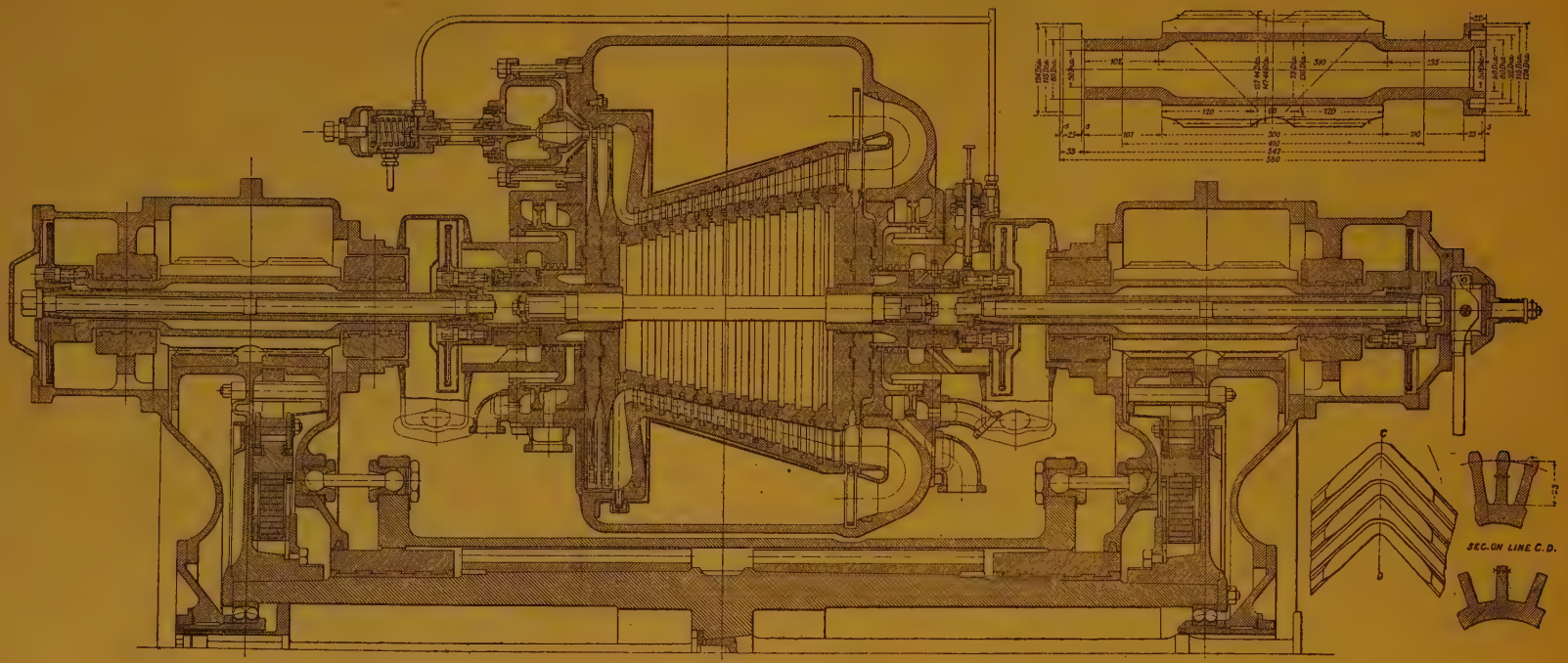


Fig. 8. — Ljungström turbine locomotive. — Section through turbine.

pulse wheel consisting of two large discs furnished with blades. It then passes through the reaction blading which is mounted on a sort of conical drum formed of a series of rings. These rings are held in position between the end-discs of the rotor by the pressure of large steel nuts screwed on to the shaft, the nuts being shaped so as to serve as the journals of the shaft. At the exhaust end the steam is turned backwards axially through a ring of blades attached in pairs to the last row of blades on the drum. The purpose of this arrangement is to shorten the turbine by bringing the steam backwards towards the centre, whilst providing at the same time a large annular area and a high blade speed for the final row of blades where the volume of the steam is very great. To prevent the exhaust steam cooling the working parts of the turbine, the drum of the stator is surrounded by a thin sheet-metal shield which protects it from direct contact with the exhaust steam.

The bearings of the turbine rotor are lubricated by oil under pressure, and the same practice is employed in the case of the bearings of the auxiliary turbines.

At each end of the main turbine is a pinion driven from the rotor shaft by means of flexible couplings. The latter are formed of a pair of flexible diaphragms joined together around their circumference and fixed respectively upon the two shafts to be coupled. A coupling of this kind connects the turbine shaft to the hollow shafts passing freely through each pinion, and similar couplings connect the ends of the hollow shafts to the pinions themselves. This method of driving the pinions relieves them of all stress which any slight want of alignment of the bearings would otherwise impose upon them.

As has already been mentioned the turbine drives the locomotive wheels by means of double reduction gear. The general arrangement of this gear is illustrated in figures 9 and 10. The pinions on the extension of the rotor shaft of the turbine engage with two wheels on the second-motion shaft. At the centre of this latter shaft is a large double-helical pinion driving the wheel on the jack-shaft. The latter carries two overhung cranks to which the ends of the coupling rods are attached. The overall gear-ratio is 22 to 1, so that a turbine speed of 9 200 revolutions per minute corresponds to about 420 revolutions per minute of the driving wheels. As the latter have a diameter of 56.3 inches, the corresponding speed of the locomotive is 70 miles per hour. On account of the necessary play in the crank-pin bearings the periodic reversal of stress in the coupling rods causes slight irregularities in the driving effort. To avoid the shocks on the gearing which would arise from this cause, sets of laminated springs have been arranged between the rings and the bosses of the wheels which engage with the pinions on the turbine shaft, thus providing a flexible spring drive.

The use of helical gearing assures a smoothness of transmission which could hardly be obtained with straight teeth. Furthermore, in order to give the teeth of the primary pinions a certain amount of flexibility their roots are separated by deep grooves, so that each tooth is formed, so to speak, on the top of a thin wall of metal.

All the gearing is totally enclosed, and special provision is made to ensure the proper alignment of the teeth. Two similar casings enclose the turbine pinions and their wheels, a third casing surrounds the second motion pinion and the gear wheel on the jack shaft. The bearings of the latter are not mounted in the casing, but in the ends of two levers pivotted at their hinder ends and provided to admit of the disengagement of the gear for the reversal of the locomotive.

Reversing is effected by inserting an idle wheel between the second motion

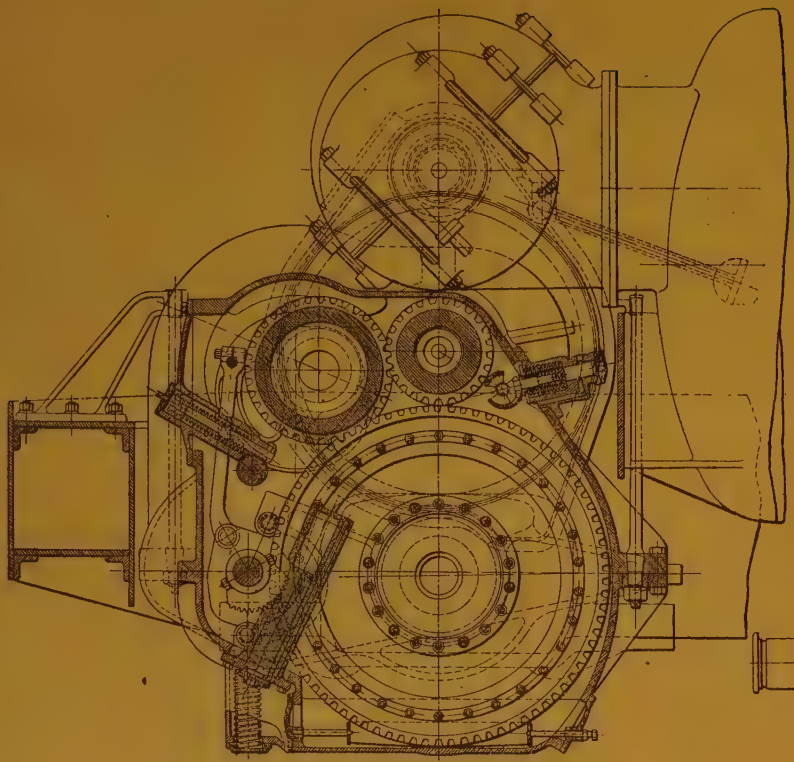
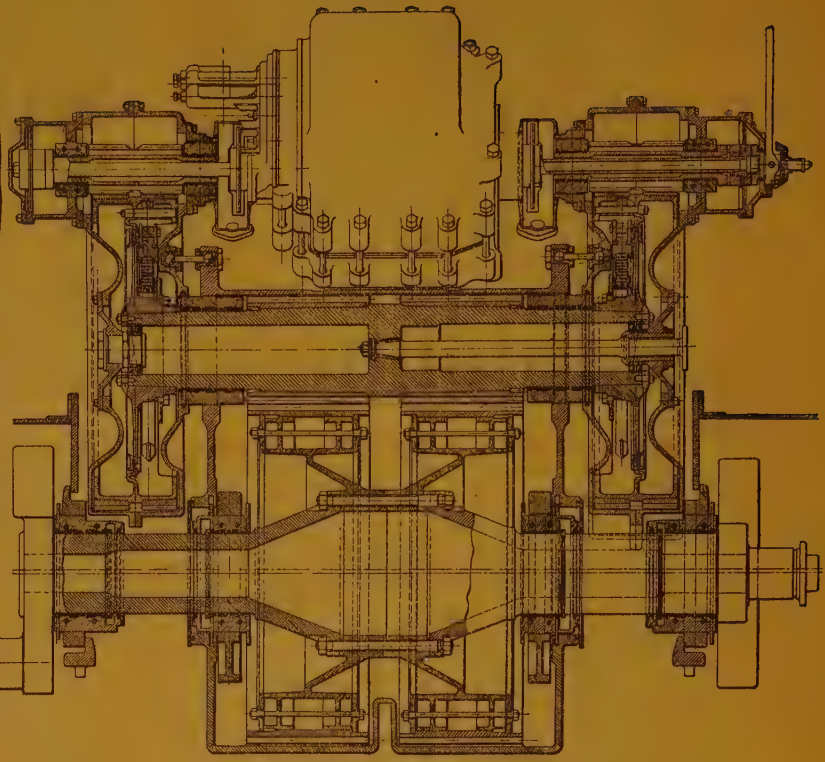


Fig. 9.



Eig. 10.

Figs. 9 and 10. — Ljungström turbine locomotive. — Double reduction gearing and reversing gear.

pinion and the wheel on the jack shaft. During forward running this idle wheel is out of gear. The two motions necessary for reversal of the locomotive, namely the dropping of the jack shaft out of gear and the engagement of the idle wheel are effected by the movement of a small hand-lever which controls the supply of oil under pressure. The mechanism actuated by the oil pressure is so designed that no alteration of the gear is possible unless the wheels are at rest. Furthermore, should the teeth of the wheels be then in such a position that the gear could not be engaged, the driver can rotate the turbine through the few degrees necessary to bring the gear into a favourable position by means of a special handle provided for this purpose. As the idle wheel has to engage with the teeth of both members of a pair of helical gears, its teeth cannot be continuous from end to end, but must consist of two sets of helical teeth running opposite ways. Each tooth therefore is broken up into series of short lengths, and the contact surface thus reduced by one half, but as these teeth are only in action when the locomotive is running backwards the teeth are amply strongh enough for the service they have to perform.

Boiler, superheater, and air pre-heater.

The firebox has a grate area of 28 square feet, the heating surface of the boiler is 1 237.8 square feet and the superheater surface 861 square feet. The comparatively small heating surface is due both to the fact that all the tubes are large ones, fitted with superheater elements, and also to the shortness of the boiler, the body of which is only 9 ft. 10 in. long. The designers have shortened the boiler by eliminating the least efficient part at the front, and have reduced the sensible heat of the escaping gases by using these gases to heat the air required for combustion. By placing superheater tubes in the whole of the 160 boiler tubes, they have obtained a superheating surface equal to 70 % of the heating surface, and thus rendered possible a high degree of superheat. The steam passes in series through the superheater tubes belonging to two boiler tubes, an arrangement which gives a high final temperature to the steam, the velocity of which is not unduly high on account of the large number of superheater elements in parallel. An arrangement is fitted for blowing soot from the boiler tubes, this consisting of a series of vertical pipes from holes in which jets of steam are blown through the tubes. The fireman can blow each vertical row of boiler tubes in turn. The same arrangement of course also cleans the superheater tubes.

The air preheater is formed of a rectangular box of sheet steel situated beneath the smokebox and containing 650 brass tubes, 8 ft. 11 1/4 in. long, 1.3 inches external diameter, and 0.059 inch thick, giving a heating surface of 1 786.8 square feet. The smokebox is divided by a vertical partition, and the gases descend from the rear portion into the preheater, flow along the outside of the tubes and then ascend into the front of the smokebox, whence they are drawn by a fan and forced up the chimney. In the front part of the preheater is a shoot in which flue dust and small cinders accumulate, and from which they can be discharged by a door. The preheater tubes open behind into a sheet iron duct by which the air passing through them is delivered to the ashpit. The entrance of the air is controlled by a shutter arrangement which can be operated by the fireman, who thus regulates the amount of air going to the furnace. The lever which opens the fire-door is interlocked with the air shutters, so that the door can only be opened when the air is shut off.

The fan which produces the draught is driven by a small turbine having a

wheel 4.72 inches in diameter, and developing 40 H. P. at 10 000 revolutions per minute. The fan has a diameter of about 23.6 inches measured over the tips of the blades. The latter are machined from the solid, and the boss, the centre of which is counterbored to give flexibility, is mounted on the end of a flexible shaft passing through the centre of the hollow turbine-shaft. At its other end the fan shaft drives an oil pump of the gear wheel type which lubricates the bearings from oil contained in a fairly large chamber which projects from the front of the smokebox, so that the oil is maintained cool (fig. 2).

Condenser.

The construction of a condenser capable of absorbing the enormous quantity of heat in the exhaust steam from the turbine, without exceeding the permissible limit of weight, or the limits of space available, is perhaps the most difficult problem which the inventors had to face. The solution upon which they decided was based upon the cooling of the condenser by means of a strong current of air, the latter being provided by three fans driven by the main turbine.

The condenser comprises a cylindrical reservoir extending from end to end of the motor vehicle and half filled with water. It is connected to the turbine by a large exhaust branch. From the reservoir the steam passes through two large connecting pipes to a second cylindrical drum of smaller diameter than the first, and situated centrally above it. The return circuit is composed of the cooling elements which constitute the working part of the condenser, and also its most original feature. These elements are formed of flattened copper tubes, sloping down on either side of the condenser and presenting an appearance somewhat like the rafters of a roof. These tubes are provided with external fins, and being placed close together, the fins from the walls of labyrinthine passages through which the air is forced by the fans. The cooling surface amounts to 10 764 square feet. Figure 11 shews the

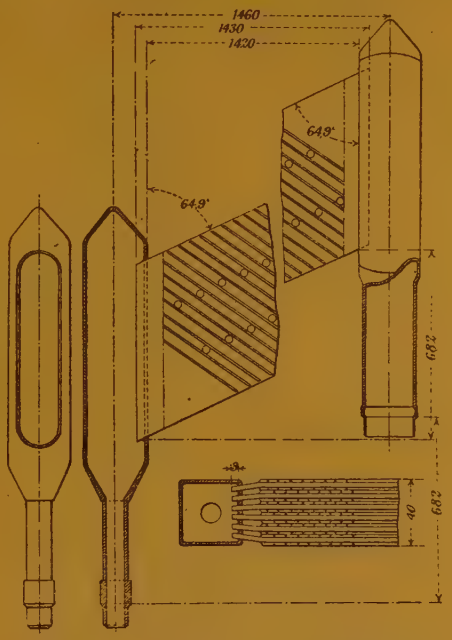


Fig. 11 — Ljungström turbine locomotive. Condenser elements.

arrangement of the condenser tube elements. They are mounted in groups of six, assembled by brazing their ends into little vertical boxes of square section, one set of boxes being placed on top of the upper reservoir, and the other on one of the longitudinal collecting pipes running horizontally along the sides of the vehicle. From these pipes the condensate is led back to the central reservoir. The manufacture of the condenser elements necessitates the use of specially designed tools. To prevent their collapse under the external atmospheric pressure, their sides, already reinforced by the fins, are dented at intervals in such a way that their internal faces come into contact at a series of points where

they meet with mutual support. The walls are 0.0295 inch thick, and they are separated by a space of 0.067 inch so that each element without its fins has an overall width of 0.126 inch.

The arrangement of the condenser fans is shewn in figures 12 and 13. They are placed on the centre-line of the vehicle above the main reservoir, their shafts being vertical and supported in ball thrust bearings. They are driven by friction wheels working against their central discs, these wheels being so mounted that they can slide along the longitudinal shaft which drives them. Thus, by moving these friction wheels along the shaft nearer to or further from the centres of the discs of the fan wheels, the speed of the latter can be varied independently of the speed of the turbine. The longitudinal shaft carrying the friction wheels is driven from the turbine by means of an inclined shaft and bevel gears on the front of the condenser car. Each fan is designed to deliver 1 412 cubic feet of air per second.

The water contained in the main reservoir not only constitutes a reserve but serves also to enable the condenser to deal with short periods of heavy duty without appreciable loss of vacuum. To utilise this water more effectively for purposes of condensation the arrangement shewn in figure 2 has been adopted, the function of which is to ensure more intimate contact of this water with the exhaust steam. In the centre of the reservoir below the level of the water there is a centrifugal pump driven by a downward extension of one of the fan shafts. The impeller of this pump is housed in a cylindrical casing from the bottom of which water is drawn in. The water is discharged over the top of the casing on to a horizontal grid from which it descends in the form of fine rain.

Experiments have been made to show the influence of the water reserve on the temperature of the condenser. With 3.96 lb. of steam passing per second to the condenser, and the fans delivering 308.5 lb. of air per second at an initial temperature of 95° Fahr., the condenser temperature never exceeded 149° Fahr., corresponding to a vacuum of 24 to 25 inches with the barometer at 30 inches. With the normal quantity of 10 tons of water this temperature is only reached after about thirty-five minutes working, which represents a run of a considerable length.

The space between the two reservoirs in which the fans work is covered above by means of the condenser elements already described, and the sides are shut in by walls formed of curved plates arranged so as to take advantage of the speed of the locomotive in facilitating the entrance of air. The arrangement will be understood from figures 1 and 4.

Auxiliary apparatus.

Water is withdrawn from the condenser by means of a condensate pump which delivers it to the feed pump. Both pumps are of the centrifugal type, and each is driven by its own turbine. The feed pump which has to overcome the boiler pressure of 300 lb. per square inch in addition to the resistance of the three feed-water heaters, consists of three impellers working in series. It is driven directly by a turbine coupled to the same shaft. The latter is flexible, and one end of it is utilised to drive an oil pump which supplies forced lubrication to the bearings. The condensate pump, which works under a low pressure only, has only a single impeller which is driven from the turbine through reduction gearing.

The air is drawn from the condenser by a steam ejector consisting of two nozzles working in series. The exhaust steam is taken to the first feed water heater.

These feed water heaters are of the ordinary type, consisting of a cylindrical

Fig. 12.

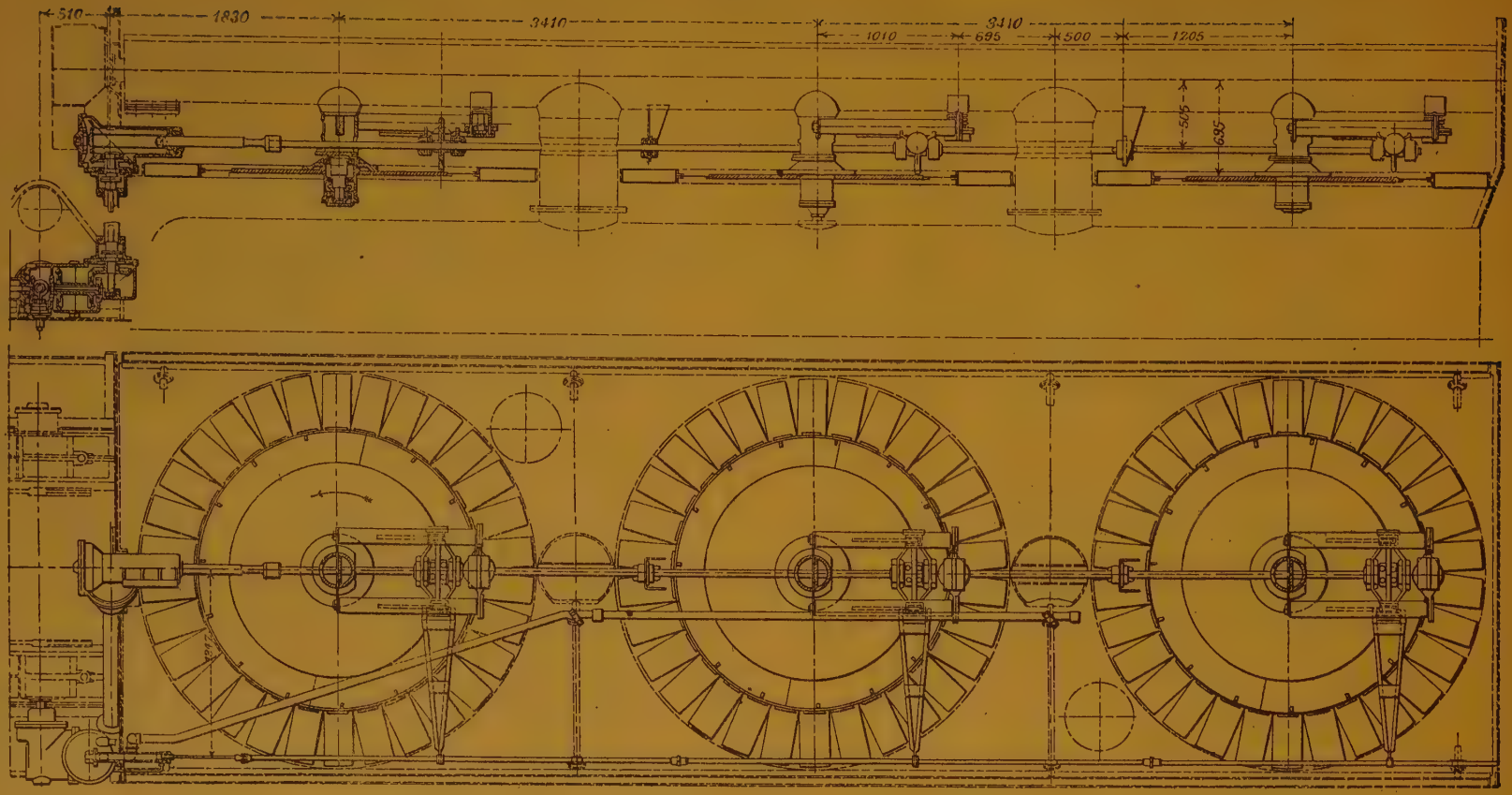


Fig. 13.

Figs. 12 and 13. — Ljungström turbine locomotive. — Fans for the condenser.

casing carrying a pair of tube plates connected by the tubes through which the water passes. The exhaust steam fills the casing and surrounds the tubes. The ends of the casing are closed by circular covers, one of which carries the inlet and outlet connections for the water. The latter makes a double pass through the heater, going first through the central tubes and returning by those around the circumference. The feed water heaters use all the exhaust steam from the auxiliary apparatus and raise the temperature of the water successively to 194, 232 and 284° Fahr. The water of condensation which comes from them is returned to the main condenser.

To complete this brief description of the Ljungstrom locomotive we will touch upon the arrangements which the inventors have adopted for protecting the working parts from dust and providing them as far as possible with the favourable conditions under which modern stationary engines operate. The whole of the coupling rods, cranks, and axleboxes of the driving wheels are totally enclosed in an oil-tight casing of sheet steel Openings in the casing, which are normally closed by detachable covers, provide access to the crankpins, and the whole of the lower part of the casing is easily removable when a general inspection is required. Every driving axlebox is fitted with a circular protecting plate which can slide in a recess in the side of the casing, to provide for the movement of the vehicle on its springs. The inner ends of the journals are protected against dust by packing-rings surrounding the axles. The journals are lubricated by oil under pressure, provided by the main oil pump.

Efficiency and test results.

As one might reasonably expect from the attention which has been paid to all points upon which efficiency depends, the results obtained from the Ljungstrom locomotive are extraordinarily good. The heat balance of the machine may be summarised by the following figures.

The pre-heating of the air recovers 7 % of the heat of the coal put into the firebox. The feedwater heaters recover from the exhaust steam from the auxiliaries a further 14 % of the heat of the coal.

Deducting the heat which is recovered, every hundred heat units developed in the furnace are accounted for as follows :

Losses by chimney, ashes and radiation	18.0 %
Losses in the turbine and by radiation	3.5 %
Power absorbed by fans . . .	3.3 %
Heat rejected to the condenser .	60.5 %
Useful work.	14.7 %

The above table shows that the thermal efficiency of the locomotive is 14.7 %, that is to say nearly double that which is obtained from the best ordinary locomotives, and an efficiency moreover which is considered very satisfactory even for a modern power station.

The locomotive was first tested by means of a special dynamometer at the works of the builders. This was of the type used in America and elsewhere, in which the locomotive is placed with its driving wheels resting upon wheels keyed to shafts carrying dynamometer brakes. It has also made numerous trial trips during which it has hauled trains under conditions similar to those obtaining in actual service. These tests have allowed many very interesting features to be noted. The tractive effort is very great at starting, when all the steam nozzles are opened; but it is diminished rapidly as the speed increases, the rate of decrease being most rapid at the lower speeds. The steam consumption is fairly high at low speeds, being higher even than that of piston-locomotives. This is due to the inefficiency with which the turbine works at such

speeds, but as soon as the locomotive is moving at a few miles per hour the turbine shews an advantage over the piston engine which increases rapidly until a speed of 15 miles per hour is reached. At 50 miles per hour the turbine locomotive requires only about half as much steam as a piston-locomotive of the ordinary type.

The condenser pressure hardly ever increases beyond 2.84 lb. per square inch, which corresponds to a vacuum of 24.3 inches. The draught in the smokebox, which can be regulated by the speed of the chimney fan, can be maintained at 4.5 inches of water.

It is needless to enlarge upon the advantages derived from so great a reduction in coal consumption as has been indicated above, and we need only mention the new possibilities thus opened out for the steam locomotive. So far as water consumption is concerned, this factor is reduced to a very small matter, and as the only water which has to be taken on board is that required to make up for the small leakages and secondary losses, the length of non-stop runs can be considerably increased. The use of the condensed steam for boiler feeding does away with frequent boiler washings, keeps the boiler clean, and diminishes the cost of maintenance.

Great credit is due to the inventors for the courage and ingenuity which have enabled them to realise in a moving vehicle an efficiency which will compare with that of the best stationary power plants. Undoubtedly improvements will yet be discovered, and possibly, indeed, the turbine locomotive has not yet attained its final form, but it is not too much to hope that the day will arrive when locomotives of the type in question will be in regular service.

E. M.

Instructions relating to reinforced concrete structures.

We give below, to put on record, the text of the main clauses of the instructions relating to reinforced concrete structures which had been subjected to public inquiry and published by the Belgian Standardization Association.

At an early date we propose to give in the *Bulletin* a comparison between the proposed instructions and the latest foreign regulations, particularly the new proposed American regulations and the German regulations.

ARTICLE 4. — In Belgium it will be taken that the temperature may vary by 20° C. (36° F.) above and below the temperature at the time of building. This range of temperature may, however, be reduced when the structure is protected from the variations in the temperature of the surrounding air (as, for example, by a layer of earth).

Explanatory note. — The figure of 20° C. (36° F.) is based on the following:

Three sets of experiments have been made, quite different in character, but all leading to practically identical conclusions :

Mr. Mesnager's experiments (1). — This experimenter kept records for a year of the variations of temperature in the interior of a concrete prism measuring 200×50×50 cm. (6 ft. 6 3/4 in. × 1 ft. 7 5/8 in. × 1 ft. 7 5/8 in.) exposed to the full severity of the weather, and he compared these observations with the temperature of the surrounding air.

He found that the variations were practically of the same amplitude but they were out of phase with each other by three or four hours. The maximum and minimum temperatures recorded during this year were +30° C. and —6° C. (+86° F. and 21° F.) or a total range of 36° C. (65° F.).

Mr. Mesnager made measurements to ascertain whether the prism showed increase and decrease of length of the same magnitude as if the mass had the temperature found at the centre. The result showed this to be the case and that the coefficient of expansion was 0.000011.

Mr. von Emperger's experiments (1).— The experimenter observed the movements at the crown of the reinforced concrete arch in the Dobernegg bridge over the Elbe, and also took note of the variations in the surrounding air. From these experiments it was found that, if account were taken of the time-lag found by Mr. Mesnager, the curve giving the variations in the observed deflection agreed almost exactly with the curve of the deflection calculated in accordance with the theory of the strength of materials, on the assumption that the whole of the bridge had the temperature of the surrounding air, and that the coefficient of expansion due to heat amounted to 0.000010.

Mr. Gehler's experiments (2). — The observer made measurements on a foot-bridge over the railway at Leipzig. The bridge was arched, of reinforced concrete with parapets, jointed at the two ends, one of the joints being carried on a slide giving freedom for horizontal expansion.

Mr. Gehler measured the displacement of the slide and from the results deduced the variations in the imaginary uniform temperature

(1) See *Cours de béton armé* (*Reinforced concrete construction*), by A. MESNAGER, Dunod, 1921.

(2) See *Der Rahmen*, by Or. Ing. W. GEHLER, Wilhelm Ernst, Berlin, 1919.

which the footbridge should have in order to produce these movements; he compared this temperature t with the temperature T of the surrounding air. He found that the variations of t amounted to only 80 % of those of T. It is possible that the friction of the slide prevented its free movement and that if this had not occurred the variations of t would have been sensibly the same as those of T. Mr. Gehler does not mention the time-lag noticed by Mr. Mesnager; it is true that he made his experiments on an arch of great height, but of very little thickness (only 20 cm. = 8 inches).

As the result of the experiments that have been quoted, M. Mesnager recommends that calculations should be based on a variation of temperature of ±25° C. (±45° F.); Mr. Gehler recommends ±20° C. (±36° F.) and finally Mr. von Emperger suggests that the figures should be:

+25° C. (+77° F.) to —15° C. (+5 F.) for thicknesses up to 20 cm. (8 inches);

+22° C. (+72° F.) to —12° C. (+10.4° F.) for thicknesses up to 50 cm. (1 ft. 7 5/8 in.);

+17° C. (+63° F.) to —7° C. (+20° F.) for thicknesses up to 100 cm. (3 ft. 3 3/8 in.).

Mr. von Emperger's figures appear to be much too low for Belgium, particularly as regards low temperatures. Now the latter are especially important in view of the fact that to the effect of drop of temperature should be *added* the contraction of concrete on setting, whereas a rise of temperature almost exactly neutralizes the effect of the contraction of the concrete on the elastic stresses.

It is therefore the lower limit of temperature, that has to be taken into the calculations, that requires to be studied closely. Now this lower limit should be greater than that of the surrounding air, because of the fact — rarely mentioned — that a reinforced concrete structure actually sets at an increased temperature owing to the liberation of heat as a consequence of the chemical reactions that take place when the cement is setting. In large masses of concrete temperatures are found as much as 30° C. (54° F.) above those of the surrounding air; temperatures of 8 and 10° C. (14 and 18° F.) above those of the surrounding air are often maintained for several days after the concrete has been made. It follows that the temperature when made is higher than it is generally believed to be, and it appears desirable that this should be taken into consideration.

These investigations show that the figure recommended by Mr. Mesnager is rather too low. Nevertheless the figure of ±20° C. (±36° F.) has been recommended here, because the Commission has not wished to lay down rules that depart too widely from existing practice.

In the greater number of large reinforced structures erected during the last few years variations of only 10 to 15° C. (18 or 27° F.) have been taken into account; the only case known to the Commission in which a range of ±20° C. (±36° F.) was taken was that of the Gmunderthal viaduct over the Sitter, in Switzerland.

It is moreover worthy of notice that the article following requires that *in addition* the contraction of the concrete in setting should be taken into consideration on the basis of a drop of temperature equal to 20° C. (36° F.), an allowance which has not been made up to the present date, except in the case of the Swiss specifications, and these, on the other hand, only consider a variation of actual temperature of ±15° C. (±27° F.).

The last part of the preceding article, relating to the reduction in the allowance for variation of temperature to be made when the concrete is protected by a bank of earth, justifies itself. The amount of the reduction requires investigation in each particular case.

ARTICLE 5. — It will be assumed that the contraction of concrete in setting will produce the same effect as a drop of temperature of 20° C. (36° F.). This drop of temperature may however, be reduced to 10° C. (18° F.) if the concreting is only done in sections and the joints are not filled in till two weeks after the concreting of the last section.

Explanatory note. — It would appear that

the only way in which account can be taken of the contraction of concrete in setting is by representing it by a fall of temperature, in considering its effect on the elastic tensile stresses. Actually the phenomenon is much more complex because the stresses — produced in concreting — are compressive in the steel and tensile in the concrete.

The magnitude of the imaginary drop of temperature to be taken into consideration, the effect of which is additional to the drop of temperature specified in article 4, has had to be investigated very closely, because of its great influence on the tensile stresses in very flat arched bridges and similar structures. In such cases it often happens that the elastic stresses due to rolling loads and dead weight, are only small in comparison with those due to the combination of a low temperature and the effect of contraction in setting. If the conditions were made too severe there would be the risk of condemning some structures that have notwithstanding given satisfaction and have stood for many years; and, on the other hand, by fixing figures that are too low there would be the risk of making serious errors.

The Commission consequently decided to submit the question to further experimental investigation, an investigation that had not, hitherto, been made on Belgian materials. It entrusted the experiments to its Secretary-reporter who made a series of measurements at the testing laboratory of the University of Ghent. The details are given in a paper published in the *Annales des Ingénieurs sortis des Ecoles spéciales de Gand* (part 3, 1921). The general conclusions arrived at were as follows:

In the case of concrete containing 350 kgr. of cement to the cubic metre (590 lb. per cubic yard) and kept in air the contraction is about 0.42 mm. per metre after six months and increases very little after that period. This contraction is almost the same for each of the three cements subjected to trials which were drawn from three different manufacturing districts of the country. The drop of temperature which would correspond to this is about 35° C. (63° F.).

This figure is not, however, that which should be taken for calculations, because it relates to *ordinary (not reinforced)* concrete. For *reinforced* concrete the figure is smaller, and is still smaller the greater the amount of reinforcement. The latter acts by partially preventing the shrinkage owing to the adhesion of the concrete: in a prismatic solid with symmetrical reinforcement, the concrete is, after a time, subject to tensile stress and the reinforcement is under compression.

The magnitude of these internal stresses depends on the mass of the parts under consideration; thus the French Commission on Reinforced Concrete found a stress of 4.6 kgr. per mm² (6 540 lb. per square inch) in the reinforcement of a prism measuring 200×100×10 cm. (6 ft. 6 3/4 in. × 3 ft. 3 3/8 in. × 4 inches), and 8 kgr. per mm² (11 380 lb. per square inch) in the reinforcement of a prism measuring 400×40×20 cm. (13 ft. 1 1/2 in. × 1 ft. 4 in. × 8 inches). This is explained by the fact that the production of these stresses is caused by adhesion.

The figure of 35° C. (63° F.) should therefore be reduced for reinforced work; examination of the results obtained by experiments, made on pieces having about the same dimensions as occur in practice, has led the Commission to the conclusion that the most rational figure for average reinforced concrete is 25° C. (45° F.). Notwithstanding this, the present article only specifies 20° C. (36° F.) as the fall in temperature equivalent to the contraction; this is done with the view that the rules laid down shall not diverge too widely from ordinary practice, which frequently does not take the contraction on setting into account at all. A certain amount of liberty is taken because the stresses developed in setting mentioned above are never taken into account; now these act by reducing to some extent stresses calculated as compressive in the concrete and tensile in the reinforcement.

The last part of article 5, relating to the reduction of the figure of 20° C. to 10° C. (36° F. to 18° F.) when the concreting is done in sections, is justified by the fact that after two or three weeks the concrete has already contracted by 50 % of the total contraction and

that, consequently, before the joints are filled in, the main part of the work — the sections — has already contracted by about one half of its total; it is only the remaining half that can be responsible for the production of internal stresses.

The stipulation in this article is analogous to that of the Swiss regulations relating to reinforced concrete, and appears to be in advance of that of French Instructions which confine themselves to specifying that account must be taken of the contraction, without stating to what extent, or by what means.

Limits of stress or fatigue.

ARTICLE 6. — The limits of compressive stress permissible in concrete must exceed neither 28 % of the ultimate strength in compression at 90 days, nor 42 % of the ultimate strength in compression at 28 days. For concrete, to the specifications given below, the following safe stresses may be allowed, without need of proof by tests that the percentages given above have not been exceeded :

a) for concrete containing 0.80 m³ of gravel and 0.40 m³ of fine Rhine sand per rammed cubic metre :

45 kgr. per cm² (640 lb. per square inch) if it contains 300 kgr. of cement;

50 kgr. per cm² (711 lb. per square inch) if it contains 350 kgr. of cement;

55 kgr. per cm² (782 lb. per square inch) if it contains 400 kgr. of cement.

b) For concrete containing 0.90 m³ of porphyry chips and 0.45 m³ of porphyry dust per rammed cubic metre :

50 kgr. per cm² (711 lb. per square inch) if it contains 300 kgr. of cement;

55 kgr. per cm² (782 lb. per square inch) if it contains 350 kgr. of cement;

60 kgr. per cm² (853 lb. per square inch) if it contains 400 kgr. of cement.

The crushing stress is to be taken on cubes measuring 20 cm. (8 inches) on the edges, kept in a damp atmosphere.

The specification for each scheme should give the maximum permissible stress, whether this is given in the above table or not, and it should also give the quality and the proportions of the constituents used for making the concrete.

Explanatory note. — The first paragraph of this article states a general rule for limiting the permissible compressive stress in concrete. This limiting stress is determined on logical grounds as a percentage of the ultimate crushing stress. There are however, practical difficulties in the way of the application of this restriction, which cause trouble in many instances, particularly in the case of works of comparatively small size: it cannot be expected that in the course of execution of such work, actual tests of the strength of the concrete should be made, or that a delay of three months should take place before the results are obtained.

It is this category of work that has led the Commission to draw up the next paragraph, that for the six mixtures of concrete given — the ones most generally in use in Belgium — it is not necessary to prepare test blocks provided that the actual stresses do not exceed the figures given. This was made possible by the fact that owing to the limited area of Belgium, it is practically always a question of the same materials being used for the work. It is understood that the stresses, given in the second paragraph of article 5, can only be permitted when the conditions relating to the execution of the work are adhered to strictly.

The general rule given in the first paragraph of this article comprises an innovation as compared with the corresponding article of the French Instructions. Actuallly it connects the ultimate stress at 28 days and that at 90 days equally with the limiting stress.

This innovation finds its justification in the fact that all concrete mixtures do not harden equally rapidly. For two mixtures of concrete A and B of the same richness, it might be found according to the cement used that :

Concrete A, at 28 days, gave 110 kgr. per cm² (1 565 lb. per square inch) ; and at 90 days,

200 kgr. per cm² (2 845 lb. per square inch);

Concrete B, at 28 days, gave 140 kgr. per cm² (1 991 lb. per square inch); and at 90 days, 190 kgr. per cm² (2 702 lb. per square inch).

According to the French instructions:

Concrete A can be loaded to 28 % of 200 = 56 kgr. per cm² (796 lb. per square inch);

Concrete B can be loaded to 28 % of 190 = 53.2 kgr. per cm² (757 lb. per square inch).

According to the stipulation of the present article, on the other hand :

Concrete A can be loaded to 42 % of 110 = 46.2 kgr. per cm² (657 lb. per square inch);

Concrete B can be loaded to 28 % of 190 = 53.2 kgr. per cm² (757 lb. per square inch).

The article as drawn, therefore, shows concrete B to be superior to concrete A, whereas the French instructions show the reverse.

Now A is very obviously inferior to B because the greater number of mishaps that occur in reinforced concrete structures, occur when the shuttering is being removed, that is to say on the average about 28 days after making. These mishaps will become less numerous the more use is made of concrete that has greater strength at the time of removing the shuttering, because this greater strength may to some extent compensate for certain defects in workmanship. In other words the object of taking both ultimate compressive strengths into consideration, that at 28 and that at 90 days, is to give a sort of premium for the use of a cement that attains a comparatively high strength at the time for the removal of the shuttering. The small complication that arises from this, so far as the actual tests are concerned is of no importance, because according to the third paragraph of article 6, the test need only be made under exceptional circumstances and in particular when the contractor desires to exceed the maximum stresses permitted without tests. It is, in fact, quite logical to specify that very severe tests shall be adopted for those cases in which it is desired to apply exceptionally heavy stresses.

The justification of the figures of 28 and 42 % are to be found in the practice of the last twenty years which has shown that they do not give rise to mishaps.

The definite figures given for the limiting maximum stresses are those of the French Commission and relate to concrete made with gravel and Rhine sand.

Those figures that relate to concrete made with porphyry chips and dust are 5 kgr. per cm² (71 lb. per square inch) higher for equal mixtures; the resistance of this concrete to crushing is actually about 10 % greater than that obtained with gravel and sand, a fact which, according to Mr. Camerman, is due to the puzzolanic character of this material.

The end of article 6 requires that the crushing test shall be made on a cube *of 20 cm. (8 inch) edge.* It is necessary to specify the size of the cube because of its influence on the result obtained : the greater the size of the cube the smaller the ultimate crushing stress as measured by the ordinary testing machines.

It follows that by loading the concrete to 28 % of its crushing strength at 90 days the factor of safety is not necessarily 100/28 that is to say about 3.6; the columns and girders in ordinary practice usually are of larger cross-section than the test cube; moreover the strength as measured by the machine on a test cube is greater than the true crushing strength of the concrete, because the bearing plates of the testing machine prevent lateral spreading from taking place and thus act virtually as hoops. All things considered it is probable that the real factor of safety for concrete subject to compression is nearer 2.5 than 3.6 and it is well that contractors should know this.

ARTICLE 8. — **The normal shearing stress on concrete (or its resistance to sliding on itself) calculated on the net area, not including inclined bars on stirrups, must in no case exceed one-third of that given in article 6 for concrete subject to compression.**

Moreover, in the case when it exceeds one-tenth of the permissible stress given in article 6 for concrete in compression, stirrups or inclined bars should be pro-

vided and the strengths of these should be calculated as though their tensile strength alone was used to relieve the concrete of shearing stresses; the steel may be loaded to the limiting stress given in article 9 for steel subject to tension.

The limiting bond stress for the adhesion of concrete to steel shall be taken at one-tenth of that specified in article 6 for concrete under compression; in making the calculations only that portion of the perimeter of the bar that is in contact with a layer of concrete, of a thickness at least equal to the reinforcement, shall be taken into account.

Explanatory note. — This article differs entirely from the corresponding article of the French Instructions, and it comprises three parts that require separate explanations.

The first paragraph is intended to determine the minimum dimensions of width of girders or ribs. This width should always be at least such that the shearing stress in the concrete, *calculated on the basis that there are neither stirrups nor inclined bars*, does not exceed one-third of R'*b*, that is 9 % (or 28/3) of the crushing stress at 90 days, or a slightly lower stress than the ultimate tensile stress of concrete without reinforcement.

By taking account of this requirement, the result will be obtained that in the great majority of cases the concrete will not crack at 45° to its axis under bending. It is true that these cracks — often invisible to the naked eye — are not a source of danger, because even when they have formed the girder still has strength to resist bending owing to the stirrups and the inclined bars; they are however detrimental to the maintenance of the work in good condition and are the source of increased stresses at the ends of the girder. In order to make the meaning of this perfectly clear, it is necessary to explain the modern conception of the part played by the stirrups and inclined bars.

Experience — and theory also — have shown that the stirrups are not subjected to an appreciable stress until cracking of the concrete has taken place and that they have no appreciable effect in delaying this cracking; they do however restrict its magnitude, because, when cracking has started, the girder — which up to that point has only acted against the bending forces by carrying a tensile load additional to that on the concrete — assumes another state of internal equilibrum and now obtains from stirrups a resistance to the bending forces. In this second phase the whole structure behaves very much as though it were a Howe truss the members of which are the concrete under compression on the one hand, and the main metal reinforcement in tension on the other hand; the vertical tension members being represented by the stirrups and the diagonals in compression are the groups of concrete strips which, though they are cracked in the direction of their length, are none the less capable of standing compression.

In the case of the stirrups, therefore, the requirement of the first paragraph of this article is intended to ensure that in the great majority of cases no cracking shall occur and the whole structure shall behave as in the first phase described above. There is however no harm in making this near to the condition which determines the commencement of the second phase, because the production of the cracks does not mean the loss of ability to withstand shearing forces, but in means that the second phase has been commenced in which the resistance to these forces is obtained from another source.

In the case where inclined bars are used this reasoning does not apply; the bars are, however, often so widely spaced that they cannot be taken to have any effect on the sometimes large masses of concrete that separate them, notwithstanding that the inclined bars, unlike the stirrups, take their share of the load from the beginning. If it is true that they delay the cracking of the concrete that immediately surrounds them, they have not the same effect on the concrete that is at some little distance from them, which further justifies the requirement given in the first paragraph under consideration.

From the foregoing the second paragraph almost justifies itself.

If, in fact, the shearing force calculated on the assumption that there are no inclined bars or stirrups is well below the tensile strength of the concrete, and does not exceed 28 % of this, there is a sufficiently large factor of safety with regard to the formation of cracks in the concrete and provision need not be made for the second phase described above; the stirrups and inclined bars then take no part in withstanding the shearing forces.

On the other hand, if the shearing force — calculated on the assumption that there are no stirrups or inclined bars — is nearer to that which would produce cracks in the concrete (that is a force between 28 and 90 % of the ultimate tensile strength of the concrete) the factor is insufficient to prevent the formation of cracks and therefore it is necessary to provide stirrups or inclined bars *which are themselves by reason of their tensile strength* capable of withstanding the shearing forces in the case of formation of cracks, and when consequently the concrete taken separately would have lost its power of withstanding the shearing forces.

As it will be seen the old idea of the stirrups being subjected to shear is completely set aside and consequently it would be useless in article 9 to specify a limiting shearing stress for the steel.

It also follows — and it is well to note this fact — that, in order that the stirrups and inclined bars may be efficient, they must be anchored properly so that they can exert tensile forces. The last paragraph of article 8 relates therefore equally to these details and to the main reinforcement.

This last paragraph of article 8 adopts the same limiting tensile stress for adhesion as the French instructions. It adds, however, that when the reinforcing bars are too closely spaced, so that they are separated from each other by less than one diameter, the whole perimeter of the bars must not be taken into account in calculating the force they can exert due to adhesion. This condition is necessary unless it is specified that in all cases the bars must be equally spaced and at least one diameter apart. The Commission did not think this advisable, in the first instance because it would sometimes be very inconvenient and would lead to the widths of girders being made larger than is usual in practice. This condition, in the second place, would prevent making overlapping joints in the bars unless the distance between the bars were increased to three diameters.

The Commission, moreover, is of the opinion that there is no serious disadvantage in placing the bars very close together so long as the adhesive strength *calculated only on those portions of the perimeters of the bars that are in contact with a thickness of concrete at least equal to one diameter* does not exceed the specified limits.

It is to be noted that the Commission has not found it necessary to require the use of hook ends for the bars; it is not because they have not been considered useful, but because cases might occur in which want of room precluded their use. No danger can result from this so long as the adhesive strength is carefully limited and the bars are of sufficient length.

ARTICLE 9. — The limiting stress in tension and compression in the reinforcement may amount to 1 200 kgr. per cm² (7.62 English tons per square inch).

This figure may nevertheless be exceeded when it can be shown by experiments that the limits adopted do not exceed either one-half of the apparent limit of elasticity (yield), nor the limit of proportional deformation (limit of elasticity) and that the elongation of the metal, measured on a length equal to $11.3\sqrt{\Omega_a}$ is at least 20 %.

Explanatory note. — This article is drawn up in the same spirit as article 6 and for the same reasons. With ordinary commercial steel (article 18) there is always an adequate factor of safety with a stress of 12 kgr. per mm² (7.62 English tons per square inch). It is not, however, possible to exclude higher stesses for higher class steels. But in cases where it is desired to adopt these higher stresses, it is necessary to specify severe conditions in order to secure adequate safeguards.

For this reason the Commission has not hesitated to base the permissible stress both on the apparent limit of elasticity and on the limit of proportional deformation, notwithstanding the fact that the latter requires delicate measurement for its determination in so far as it requires appliances of precision. The consideration of the true limit of elasticity (proportional deformation) appears essential because it is this which gives the point at which the coefficient of elasticity of the steel commences to diminish; now this diminution involves a change in the distribution of elastic stresses in a reinforced concrete element. It is always less than the apparent limit of elasticity (yield) and it is of importance to ascertain that it is not less than half of this, for in this case, it would appear to be dangerous to adopt this half as the limiting stress.

Calculations of strength.

ARTICLE 11. — In the calculations for the strength of reinforced concrete structures, account must not only be taken of the most unfavourable external agencies, including the combination of wind and snow to which the structures may be subjected, but also the effects of temperature and of shrinkage of the concrete in setting, the latter in all cases other than those of works which the results of experience show may be roughly considered as subject to free expansion.

However, in the case where the coincidence of all the forces simultaneously at their maximum value appears outside the range of practice, such dimensions may be adopted as will fulfil the two following conditions :

a) That the elastic stresses shall not exceed those permissible under articles 6 to 10 under the action of all the forces the simultaneous occurrence of which comes within the range of practical possibility;

b) That the elastic stresses shall not exceed 1.75 times those permissible under articles 6 to 10 under the simultaneous action of all the forces whatsoever. In the calculations for the bending moments, for the shearing forces and the longitudinal forces due to the effects of temperature and of shrinkage in setting, the figure of 0.000011 shall be taken as the coefficient of linear expansion for reinforced concrete, and 200 t. per cm^2 (1 270 English tons per square inch) as the coefficient of elasticity of concrete.

Explanatory note. — It is well to notice the fact that, according to this article, it is necessary to take account of the *simultaneous* action of the most unfavourable external forces (which are not necessarily the largest), of the effects of climate, and of shrinkage in setting.

By « works which the results of experience show may be roughly considered as subject to free expansion » the Commission takes into account both those that are subject to constant load and those — such structures covering only a small area in plan — for which everyday experience has shown that the effect of temperature variation and of the shrinkage of the concrete are negligible.

The second paragraph of this article takes special account of very exceptional cases, such for example, as when in the pit head derrick of a mine the cable breaks at the same moment that a wind of maximum intensity is blowing. It would not be reasonable to require that, in such cases, the two loads should be added, and to arrange that under these conditions the stresses should not exceed the usual values.

It is however essential that, even should such exceptional cases occur, the structure should not suffer damage; it is this that gives the reason for the requirements relating to the calculation in this case. The figure of 1.75 adopted as the ratio between the permissible stress in this case and the usual permissible stress is obviously quite arbitrary; it was chosen however so that it remains slightly below the limit of elasticity of the steel.

The last paragraph of the present article is

essential if the requirements of articles 4 and 5 are to have a definite meaning. The effects of variation of temperature and of shrinkage depend actually as much on the coefficient of expansion due to heat and on Young's modulus as on the actual or assumed range of temperature considered.

The value of the coefficient of expansion by heat has been dealt with in relation to article 4; that for the coefficient of elasticity will de bealt with under article 13.

ARTICLE 12. — The calculations for strength will be made according to scientific methods based on experimental results, and not by empirical methods. They will be deduced either from the usual rules for the strength of materials or from principles which offer at least the same guarantee for accuracy.

Explanatory note. — This regulation must be taken as quite general, because it would be impossible to lay down a definite method of calculation without placing an obstacle in the way of the continual progress that is being made in this respect.

It is specially to be noted here that the permissible limiting stresses given in articles 6 to 10 are only justifiable when the calculations are made with all the care that is practically possible at the present day.

If, for exemple, it is a question of a (Warren) triangular truss girder, it would be wrong to interpret these instructions as meaning that the various elements could be loaded up to the stresses given in articles 6 to 10, *in the case where the calculation dealt only with primary forces*, the forces that are based on the assumption that there is free jointing at the junctions. This is not the meaning which the Commission desires to give to the text which it has prepared. The stresses given in articles 6 to 10 are only permissible if account is taken in the calculations of so called « secondary » bending moments due to rigidity of the joints.

If, to take another example, it is the question of calculating the columns for a building, it would be wrong to make the calculations for them as if in simple compression and to take the safe stresses given in articles 6 to 10. The girders carried by the columns are actually made in one piece with them and produce bending moments in them. It is only by taking these « secondary » moments into account that the safe stresses given in articles 6 to 10 can be applied.

The preceding does not mean that the Commission desires to force engineers to make exact calculations of these « secondary » forces, although this calculation has, in many cases, been adopted as a part of ordinary practice.

If, as a result of the experience he has acquired, a constructor thinks that there is no need for him to make this calculation there is no objection to his so doing, provided that his experience tells him to allow safe stresses that are less than those specified in articles 6 to 10, so that it may be capable of proof, in the event of a dispute, that, when account is taken of the secondary forces, the limiting stresses specified in those articles are not exceeded.

Some foreign regulations specify that in making the calculations for columns, the safe stress on concrete should be taken as only 80 % of that used for flooring and girders; on the other hand they accept the calculation for the load as one of simple compression. In this manner account is taken of the secondary forces indirectly by the reduction of the safe stress in details — such as columns — in which these forces attain their greatest magnitude.

This methode has the disadvantage of admitting by deduction that the secondary forces increase the primary forces to the extent of 20 % in all cases; this view errs sometimes on the side of too great prudence and sometimes of too little. It would seem preferable to consider each case separately and to keep to a general rule that the total stress, due to the combined primary and secondary forces, should not exceed a definite limit.

ARTICLE 13. — In the calculations for parts subjected to bending the value $m = 15$ will be adopted as the ratio between the coefficient of elasticity of steel and that of concrete.

In the calculations for parts subjected to compression only, the value of *m* shall be taken as equal to 12.

Explanatory note. — This article differs entirely from the corresponding regulations given in the French Ministerial circular letter which advises the adoption of a value for *m* that varies with the diameter of the reinforcement and the spacing of the transverse bars.

The Commission has thought that it was advisable to subject the problem to further investigation in view of the great differences and even contradictions existing between the foreign regulations. The work was entrusted to the Secretary-reporter who made a series of experiments in the Testing Laboratory of the University of Ghent. The results obtained from these experiments and the conclusions to be drawn from them are set forth in a paper entitled « Experimental study of the coefficient of elasticity of concrete (1).

The reader who desires to know the reasons for the regulations made here with regard to the value of *m*, is referred to this paper for information.

ARTICLE 14. — The resistance of concrete to tension shall be taken into account in determining the strains and in all calculations in which strains are a factor. In determining the local load on any part, this resistance shall always be assumed as of zero value for the part in question.

Explanatory note. — The regulations given in this article have already been accepted in ordinary practice and are proved in many treatises.

The words « and in all calculations in which strains are a factor » mean that account should be taken of the change of dimension of the concrete in calculations intended to eliminate indeterminate quantities in a superstatic structure. The superstatic forces depend in fact on the modification in the strains caused by the tranverse reinforcement.

It follows that the value of the moment of inertia to be used in a calculation for determining strains, should be calculated on the basis of *all* the concrete (whether in tension or compression) and that the quantities M, N and T. that are found by such calculation, are applied at the centre of gravity of the section so defined.

If it is true that it is necessary to take account of the strain of the concrete in making the calculation for change of dimension, because this corresponds to what actually takes places, it would be dangerous to use it in the calculations for any particular part; it is quite possible that, owing to shrinkage in setting for example, the concrete may be cracked in this part.

ARTICLE 19. — Except when otherwise specified, the joining of bars by welding shall not be allowed under any circumstances.

Explanatory note. — The Commission has thought it necessary to forbid welding because the results obtained at present by this process are too irregular and also too uncertain.

ARTICLE 25. — The distance between the main reinforcing bars in flooring slabs shall not exceed twice the effective thickness of the slab.

In a case where a slab shall be considered for purposes of calculation as bent in one direction only, transverse reinforcement should be provided in the other direction; the distance between these reinforcing bars shall not exceed five times the effective thickness of the slab and the volume of these bars per square metre shall be equal to at least one-fifth of that of the main reinforcement.

Explanatory note. — This article which primarly is not based on theoretical considerations, but rather on good general practice, only gives the maximum figures which must not be exceeded. There are many cases in which it is advisable that these distances between reinforcing bars should not attain the

(1) See, « Étude expérimentale sur le coefficient d'élasticité du béton », in the *Revue universelle des Mines* (1 January 1922).

maximum permissible limits. Thus in a slab having an effective thickness of 30 cm. (11 3/4 inches) the transverse reinforcement would never be spaced at $5 \times 0.30 = 1.50$ m. (4 ft. 11 in.) apart; but, on the other hand, in a slab 6 cm. (2 3/8 inches) in effective thickness a spacing of $5 \times 6 = 30$ cm. (11 3/4 inches) is quite the correct figure.

It is the business of the constructor to know what are the most suitable spacings for the reinforcing bars; the requirements of this article are intended to ensure that in the more common cases a solution differing radically from good ordinary practice should not be adopted.

ARTICLE 26. — In commencing the construction of details that involve reinforcement in compression, the reinforcement should be anchored transversely in all directions in which buckling of the individual bars is not otherwise prevented; this anchorage should be ensured by binding or stirrups so spaced that the distance between them shall not exceed thirty times the diameter of the bars that are anchored.

Explanatory note. — This article is to some extent justified by Tetmayer's law: for a distance of 30 diameters apart the factor of safety for buckling of any individual bar, if supposed to be quite free between two binding bars, is about 2, just as in the case of reinforcement that is subject either to tension or compression.

(To be continued.)

R. D.

[625 .142.2]

Preservative treatment of ties and timber (1),

By F. C. SHEPHERD,
ASSISTANT CHIEF ENGINEER OF THE BOSTON & MAINE RAILROAD.

Figs. 1 and 2, pp. 256 to 259.

(*Railway Review.*)

We have today gradually reached the point where the supposedly inexhaustible supply of timber has dwindled to so small and definite a quantity that there has been in recent years a marked increase in wood preservation with the result that in 1921 two hundred million cubic feet of lumber were treated as a preventative to decay. As indicated in the attached chart the actual amount treated in 1921 was three times the amount treated in 1909.

The railroads are today the largest users of treated timber, taking over 84 % of the output of the wood preserving plants in the United States, consisting of tie and railroad timbers, and the quantity of such material treated is increasing each year, it being estimated that at the present time out of approximately one hundred million tie renewals annually, over 50 % of the same are treated by or for the various railroads before installation into their tracks. Statistics for 1921 show that 55 383 515 ties were treated before installation in the track, during that year, such ties being yellow pine, oak, Douglas fir, Western pine, beech, gum, tamarack, birch, maple, elm and hemlock.

In 1908 the committee on ties, of the American Railway Engineering Association, reported that « after careful canvass made through many of the railroads in the country, the committee finds that in the judgment of its members about 87 % of our first-class timber is destroyed by decay and about 67 % of the softer woods fail from the same cause ».

Decay in timber is due to the action of low forms of plants called « fungi » which feed on and destroy the wood tissues. To preserve wood from decay it is necessary to prevent the growth and attacks of the organisms. In order to live and develop, wood-destroying fungi require a temperature favorable for growth and certain amounts of air, moisture and food. If one or more of the four essentials is eliminated, fungi cannot live and, as far as decay is concerned, wood will remain sound indefinitely. The basic problem in wood preservation, therefore, is to eliminate one of the four essentials necessary to the growth of the fungi.

Wood-destroying fungi require but a small amount of air and thrive at temperatures that prevail most of the year. Prevention of decay by control of air supply or temperature is, therefore, impracticable except in the case of timbers that are deeply buried in the ground or continually submerged in water. It is only by the elimination of one of the other two essentials, moisture and food, that wood may be rendered decay proof.

Wood under roof can be kept dry

(1) Abstract of a paper read, on 12 December 1922, before the New England Railroad Club.

enough to prevent decay if there is proper ventilation. In the case of ties elimination of moisture is usually impracticable. The most effective method of preventing decay in such timbers is to poison the food supply of the wood-destroying fungi. It is upon this principle that modern wood preservation is based, the practice being to treat the wood by injecting a toxic chemical which renders it poisonous to fungi. An effective wood preservative must not only be toxic against fungi, but must be a substance that will readily penetrate wood and at the same time will not volatilize or leach out.

The principal substances which have been used in this country in such preservation work have been chlorine of mercury, zinc chloride and coal-tar creosote, the advantages of these preservatives having been determined largely by the question of initial cost. While the wood preserving industry was in its infancy and was regarded as a somewhat doubtful undertaking, the substances usually selected were those which were obtainable at the lower cost.

The methods followed in applying preservative treatments to timber may be classified into three groups :

1° Surface application, or the coating of the timber with preservative by means of a brush or spray;

2° Open tank treatments, or the immersion of the timber into preservative in open tanks;

3° Pressure treatments, or the immersion of the timber into closed tanks or cylinders with the application of pressure above atmospheric to force the preservative into the wood.

The application of the preservative by means of a brush or spray is, of course, the simplest and cheapest method of treating timber, but it is the least effective. It can be used only with preservative of the oil class, and, at best, gives but slight penetration. Such method is confined largely to the butt treatment of poles and posts, and is usually employed only when the quantity of the material to be treated or the location does not warrant the installation of equipment for treatment of a more efficient process.

In the open tank treatment several different methods are employed and varying results obtained. The mere dipping of the material into the preservative, as practiced in the butt treatment of poles or posts, is, of course, an improvement over the brush or spray application. A more efficient process consist of a prolonged bath in heated preservative, relying on the absorptive properties of the wood to secure penetration. This method is best adapted to the treatment of small quantities of timber or for use with a preservative that is corrosive to iron. It is a rather slow process and usually expensive, as the quantity of material treated at one time is small and as the preservative must be kept hot for several hours.

The open-tank method that gives the best results employs the pressure of the atmosphere to secure penetration of the preservative. The material is first placed in a bath of hot preservative for several hours. This results in the expansion and, to some extent, the expulsion, of the air and moisture in the wood. The timber is then either left in the preservative, which is gradually cooled, or is transferred to another tank containing preservative; or the hot preservative is removed and the tank filled with cool preservative. The cooling of the timber, effected in either way, causes a contraction of the air and moisture remaining in the wood, resulting in the preservative being drawn into the wood in a larger amount and to a greater depth than if the material is simply steeped in hot preservative.

It is evident that in open tank treatment the equipment, as well as the methods used, is simple and of no particular interest, and it is only in the treatment

of timber under pressure in a closed cylinder that the methods now employed are interesting from an engineering standpoint.

The pressure process has, as its prime object : 1° the distribution of the preservative throughout the wood as uniformly as possible; 2° the securing of an absorption of a sufficient quantity of the preservative to insure the results desired. The essential feature of all pressure methods is the use of pressure to force the preservative into the wood. This is accomplished in several ways, the kind of wood, the use for which it is intended, or the kind of preservative used, making it necessary or advantageous to vary the methods employed. The timber is treated in closed retorts or treating cylinders built to withstand a pressure of 250 lb. per square inch and equipped with steam coils for heating the preservative.

Pressure treatment may be grouped into two classes, as follows :

a) Full-cell process, the object of which is to fill the intercellular spaces of the wood as completely as possible with preservative;

b) The empty-cell process, the object of which is to secure as thorough and deep a penetration as possible with the use of a minimum quantity of preservative.

When the preservative used is creosote the full-cell treatment is known as the Bethel process; when zinc chloride is used, as the Burnett process, and when a mixture of creosote and zinc chloride is the preservative, as the Card process. In all three processes the methods used are the same.

In the full-cell process the timber is placed in the retort, a vacuum is drawn and without breaking the vacuum the retort is completely filled with the preservative fluid. The vacuum not only accelerates the entrance of the preservative into the retort, but also makes it possible to force the preservative into the timber more quickly and with less pressure than is the case when the preservative must displace or compress the air in the wood. After the retort is filled additional preservative is forced into the cylinder by means of pressure pumps, the pressure being gradually raised to and maintained at 125 to 180 lb. per square inch, until the required amount of preservative has been forced into the wood. The pressure is then released, the preservative drawn from the cylinder, and, as a rule, another vacuum is drawn, the object of this final vacuum being to remove the surplus preservative so that the timber can be removed from the cylinder as soon as possible.

In the empty-cell process no preliminary vacuum is employed, and to enter the wood the preservative must therefore displace and, to some extent, compress the air in the wood.

There are two empty-cell treatments, one known as the Lowry process and the other as the Rueping process. The difference between these two is that in the Rueping process the entrance of the preservative into the wood is further retarded by subjecting the timber to an initial air pressure of from 50 to 75 lb. per square inch, after which the preservative is forced into the cylinder at a higher pressure. After the treating cylinder is filled the procedure in both empty-cell processes is practically the same as in full-cell treatments, except that the final vacuum is held longer. The results obtained, however, are quite different, as in the two empty-cell treatments the release of the pressure and the removal of the preservative from the retort permits the expansion of the air compressed in the wood. The effect of the final vacuum is to cause further expansion, and to some extent, expulsion of the air in the wood and a corresponding expulsion of a portion of the preservative that was forced in during the pressure treatment. The result is a thorough penetration

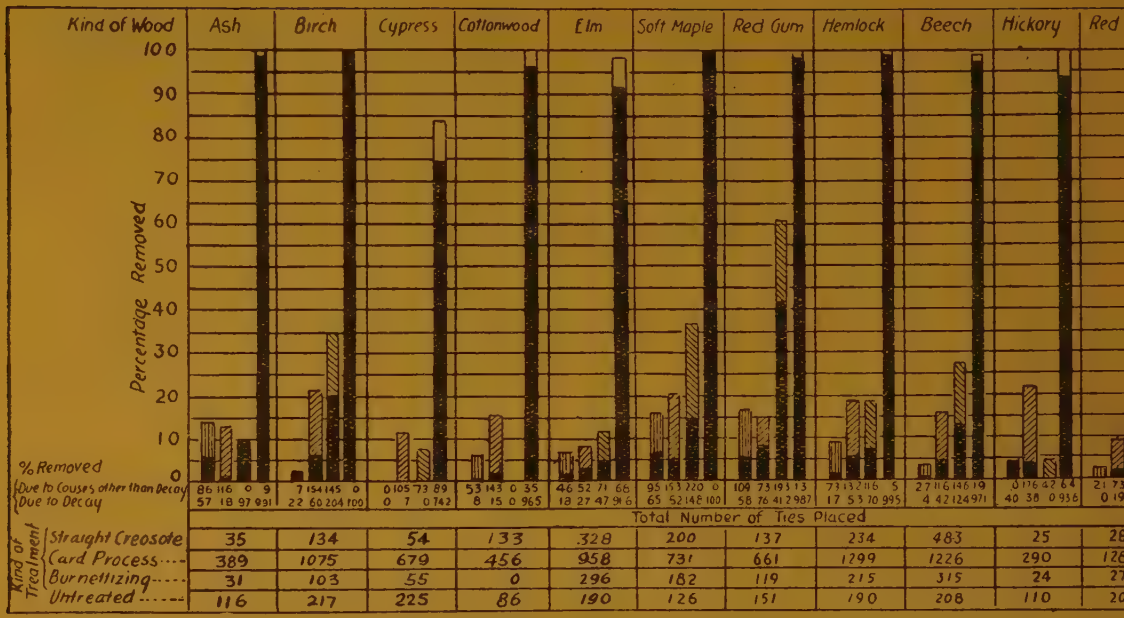


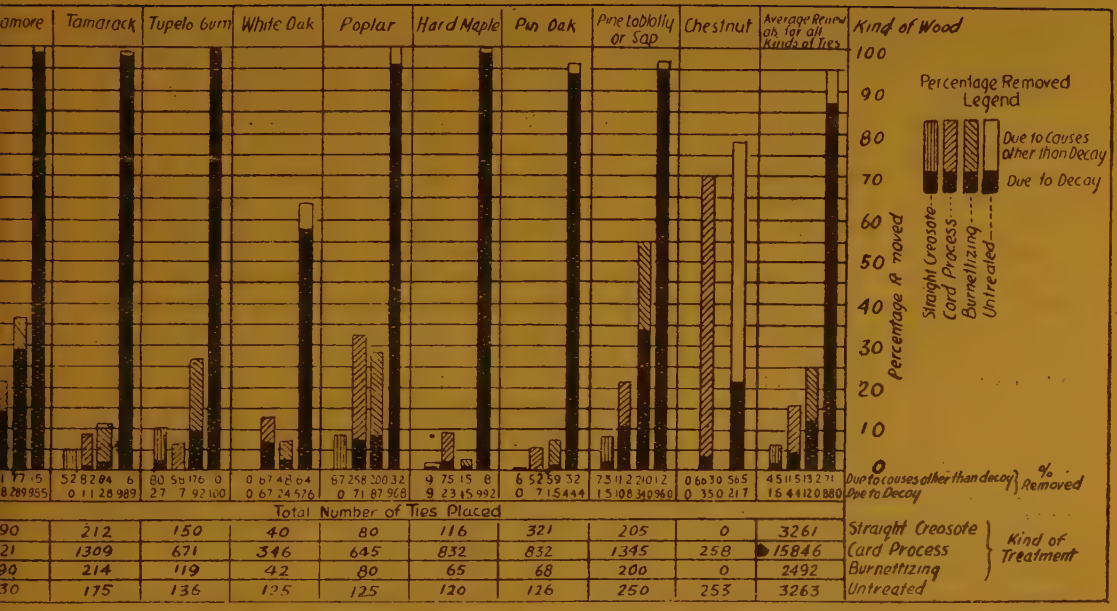
Fig. 1. — This chart shows the results of a twelve-year period of investigation on all tracks installed by the Chic

with a minimum amount of preservative. Empty-cell methods are used almost entirely with creosote and in treating timbers which do not require the complete filling of the interstices of the wood. The cost of such a treatment is considerably less than by full-cell processes, as from 25 to 40 % less preservative is required.

Freshly cut green ties and timbers contain a large quantity of water, a considerable part of which must be removed before the timber can be properly treated with preservative. The removing of this water is called « seasoning ». Seasoning not only prepares timber for its injection with preservative, but also increases its strength, stiffness and hardness, reduces its weight and renders it less likely to check and warp when put in use.

The methods of seasoning may be grouped into two general classes : 1° natural or open-air seasoning, and 2° artificial methods including kiln drying, seasoning in saturated steam and seasoning in hot oil. Kiln drying is employed in seasoning the finer grades of lumber, but is rarely used in preparing timbers and ties for treatment with preservative. Seasoning in saturated steam or hot oil is used when ties and timbers must be treated before they can be properly air seasoned and in localities where air seasoning is difficult or unsafe.

Air seasoning is a safe, economical and very effective method of preparing ties for treatment and is the method commonly used in the United States with the exception of some of the districts in the South where conditions are such that ties are likely to be damaged by decay before they can be seasoned. Air seasoning is accomplished by exposing timber to the sun and wind. As soon as timber is cut it immediately begins to lose water by evaporation and, if the timber is properly exposed, this



lington & Quincy Railroad. The long black lines tell a graphic story of the mortality of the entreated tie due to decay.

evaporation will continue until the moisture content of the wood reaches an equilibrium with atmospheric moisture when the timber is said to be air seasoned.

Ties should peeled, that is, the bark removed, before they are treated and, except under unusual conditions, before they are stacked for seasoning. In most cases peeling should be done as soon as possible after the ties are cut, in order to save freight and prevent deterioration.

When there is not sufficient time for proper air seasoning or the conditions are such that ties cannot be airdried without danger of deterioration, the process of seasoning in saturated steam is often employed. The ties are placed in the treating cylinder and live steam introduced until the pressure is raised to about 20 lb. This pressure is maintained for a period of from two to five hours, depending on the kind of wood and its condition. After the steam pressure is released the temperature in the cylinder is maintained by means of heating coils and a vacuum of from 21 to 24 inches is created and held for from one to two hours to exhaust the vaporized moisture.

Steaming carries with it the danger of injury to the wood. If the pressure employed is too high or of too long duration, serious checking and marked decrease in the strength of the wood may result. Steaming does not dry the wood and, under some conditions, increases the moisture content. It should not, therefore, be employed when ties are to be treated with creosote unless the ties cannot be air seasoned. For seasoning ties to be treated with zinc chloride solution, steaming is not so objectionable and is quite often employed to make possible the thorough treatment of partly seasoned ties.

Seasoning in oil is employed on the Pacific Coast in connection with the

treatment of Douglas fir. The ties are placed in the treating cylinders and creosote oil admitted until the ties are submerged, the temperature of the oil raised and maintened at from 220 to 260° Fahr. This gradually vaporizes the water in the wood. To properly oil-season ties requires from twelve to twenty hours, and the process is, therefore, a rather expensive operation.

Ties cut from most woods have a tendency to check while seasoning, the checking being caused by the outside of the tie drying faster than the inside. After a time the surface will shrink until it can no longer extend around the comparatively moist interior and so will be drawn apart in checks. Excessive checking can be controlled and prevented by proper piling and the use of « S » -irons. Where the end of a tie shows a well defined initial check, « S » -irons or other similar devices should be driven across the check in the end of the tie to prevent splitting during seasoning or after treatment. The commonly used type of « S » -iron is made from strips of steel 1/8 inch thick and 3/4 inch wide, beveled on one edge and bent in the form of the letter « S », 4 to 6 inches in length overall.

Checking of some hardwood ties, particularly ash, oak, hickory and beech may result in the splitting of the end of the tie. When this occurs the tie may be salvaged and made serviceable by bolting. The split end is drawn together in a large clamp and a bolt inserted.

Warping or twisting of timbers during seasoning is due to unequal shrinkage in different parts of the stick. Switch ties and long timbers cut from some hardwoods are very apt to warp and twist if not properly piled, but in cross ties this condition rarely becomes serious enough to be objectionable.

The principal preservatives in use at the persent time are zinc chloride and creosote oil.

The zinc chloride is a metallic salt, containing little free acid, not more than a trace of iron and about 94 % of soluble chloride of zinc. It is placed on the market in drums, holding 1 000 lb. each, of concentrated zinc chloride or as a 52 % solution in tank cars.

Creosote is a dead oil of coal-tar and that portion of coal-tar which distills between 200° and 355° C., and which is sometimes mixed with residual oils from the manufacture of crude carbolic acid, naphtolene and anthracene. The specific gravity ranging from 1.011 to 1.1.

Zinc chloride is manufactured in the United States, but there is not sufficient creosote oil manufactured here to supply the demand, and, consequently, it is necessary to secure the additional supply from Europe. The foreign creosoting oil is delivered in tank steamers in quantities of from 750 000 to 1 000 000 gallons, at temperatures ranging between 100 to 120° Fahr.

In the earlier periods of wood preserving in this country the chief material employed was zinc chloride, but since 1900, with the gradual demand for obtaining a longer service from treated timber and with the improvements in creosoting methods through the development of the Lowry and Rueping processes, there has resulted a more extensive use of creosote, and it is now generally considered that coal-tar creosote is the best preservative for wood, this belief being based on long experience obtained both in Europe and in this country.

This increased use of creosote is clearly shown in the attached chart, although during the period of the World war, on account of the cutting off of the foreign supply and the appropriation of much of the creosote oil in this country by the government, preservative users were forced to zinc chloride, the chart showing that for a short period the use of chloride exceeded that of creosote, although this condition is now changed and the use of creosote is again on the rapid increase.

As to the merits in the use of zinc chloride or of creosote the following conclusions submitted by the committee on wood preservation of the American Railway Engineering Association in 1919 sums up the general aspects of the preservative

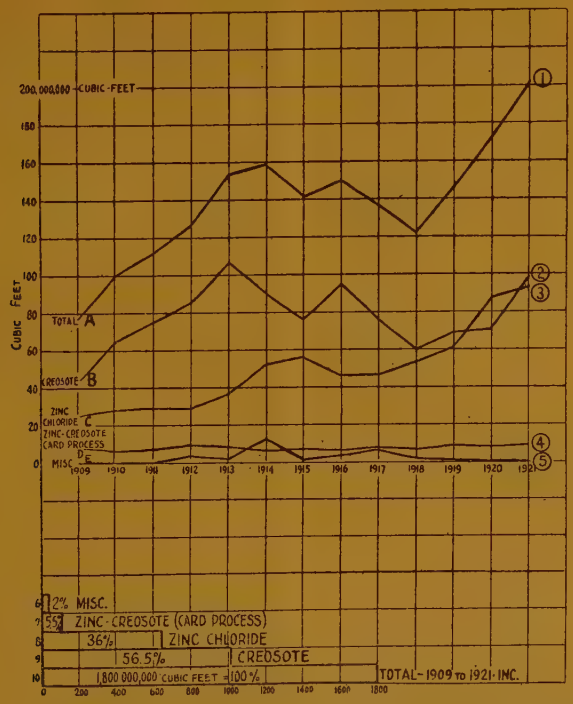


Fig. 2. — Chart illustrating wood preservative treatments in the United States, 1909 to 1921, inclusive.

situation as obtained by them, after considerable study :

1° That creosote is the best timber preserving agent known for all purposes and by reason that its composition is not affected by either rainfall or temperature, and in addition has a lubricating effect on the wood which diminishes the injury due to mechanical wear, and this combination of qualities places it at the head of all treating preservatives;

2° That where for economic reasons creosote oil is not available or other conditions of maintenance will not justify the expense for creosote treatment, the adoption of zinc chloride is without question justified in the treatment of ties. Climatic conditions will go further in determining the economy of this treatment than in any other, and as one can unquestionably figure on doubling the life of the untreated timber by its use and in dry climates this life will undoubtedly be extended;

3° That in localities where rainfall is excessive and with a humid atmosphere where good zinc chloride treatment would be unfavorably influenced by leaching, and in any climate where checking of the timber is likely to be

excessive, or mechanical abuse of the fibre is extreme, and it is not considered possible to secure a straight creosote treatment, the introduction of some lubricating agent with zinc chloride will have a beneficial effect in retarding the destruction of the timber from the above causes.

A fair comparison of the merits of these two materials may be briefly stated in the fact that untreated ties ordinarily giving six to seven years life will give from ten to twelve years life treated with zinc chloride and from fifteen to twenty years life treated by creosote.

A particularly good illustration of the comparative values of zinc chloride and creosote is shown in figure 1 showing the result of a twelve year period of investigation on the Chicago Burlington & Quincy Railroad, as published by their timber agent, Mr. Waterman, in 1921.

As to the value of the various creosoting methods, that is Bethel, Lowry and Rueping, it is evident that any of these processes will give an equal life to ties and timber so that the final comparison is the cost or the least amount of creosoting oil actually retained by the timber, with the sap wood completely penetrated and with some penetration of the heart wood, the result being that we gradually eliminate down to the Lowry and Rueping processes and at this point reach a probable equal result as to methods.

A typical treating plant includes : 1° a yard for storage, seasoning and handling of ties and timbers; 2° a boiler plant for furnishing steam for heating and treating cylinders and tanks and for the treatment of timber with live steam and for furnishing power; 3° tanks for the storage, measuring and mixing of preservatives; 4° a treating building contatining retorts or treating cylinders and equipment for conducting the different steps of the treating operation; and 5° where possible a plant for the adzing and boring of cross ties and timbers before treatment.

A plant designed for the handling of one million ties per year will require an area of possibly 50 to 75 acres, preferably extending a distance of some 5 000 feet along the line of the railroad. Storage yards where timber and ties are seasoned for treatment should be located so as to secure the full benefit of prevailing winds and should be on firm, well-drained ground which should be kept free from bark or scraps of wood, both to reduce the chances of infection and lessen the fire hazard. Such a yard should have a storage capacity equal at least to the capacity of the treating cylinders for a minimum seasoning period.

To facilitate operation and to secure the best seasoning results, the yard should be divided into sections, each of which should contain ties or timber that would become seasoned at about the same time.

Ties and timber are unloaded direct from incoming cars to the storage piles and, when ready for treatment, are loaded on to tram cars holding usually from 50 to 75 ties, which run directly into the cylinders in the treating plant. These tram cars are either narrow or standard gauge, the narrow gauge trams requiring, of course, a second set of tracks or third rail combination and narrow gauge equipment for handling the same, while with the standard gauge trams it is unnecessary to provide for a second set of tracks and one locomotive therefore may serve not only the storage yard, but the treating plant.

The treating cylinders are usually 7 feet in diameter for the narrow gauge trams, and 7 1/2 feet in diameter for the standard gauge trams, these cylinders usually being from 80 to 150 feet in length, so that a single charge for treatment of ties will carry from 600 to 1 000 ties.

The average time required for the treatment of ties is from four to six hours. After the treatment the ties are then moved on the tram cars to a loading

track, where they are loaded directly into gondola cars and shipped away for use or for storage along the right of way of the railroad.

An effective and economical timber treatment requires that the amount of preservative retained be within certain limits. To insure such retention the injection of the preservative must be carefully controlled and the amount retained after completion of the treatment must be accurately measured. The supply tanks from which the preservative is forced into the treating cylinders are mounted on scales and readings in lb. taken direct from the scale beams during treatment.

Such readings show the amount of preservative absorbed and the progress of the treatment without making corrections for temperature. This gives the treating engineer positive control of the operation and enables him to regulate the amount of preservatives used and makes possible uniform, accurate and economical treatment. Supplementing the working tank scales and as an additional check on the amount of preservative used, it is possible by use of railroad track scales to weigh the ties and timber immediately before and after treatment, which will give the exact amount of preservative retained in the timber.

Standard practice, as provided by the committee on wood preservation of the American Railway Engineering Association, provides that treated ties shall retain an average of 6 lb. of creosote oil per cubic foot which will permeate all of the sap wood and as much of the heart wood as is practicable; for bridge timber 8 to 12 lb. per cubic foot; and for piles, especially in connection with protection against teredo, the amount retained to be not less than 15 lb. per cubic foot of wood.

In treated ties or timber a large part of the preservative is retained in the outer portions and the surface is, to a large extent, sealed by the preservative. When a timber is framed or a tie is adzed and bored after treatment a portion of this well treated exterior is removed and water and decay germs are admitted to the less thoroughly treated interior.

All framing of timbers and adzing and boring of ties, should, therefore, be done before treatment, as this not only makes it unnecessary to break the seal formed by the preservative, but results in a more thorough treatment as the framing and boring facilitates the entrance of the preservative.

The practice of adzing ties to give a uniform bearing surface for the rail or tie plate and boring to increase the holding power of spikes does much to lessen the mechanical wear and is being generally adopted by railroads and other users of treated ties. By the use of modern tie-preparing machines such work can be done at the treating plant much more quickly, cheaply and accurately than by hand, and on this basis it is recognized as good practice to include an adzing and boring machine in a modern treating plant.

The treatment of ties against decay is now well beyond any experimental stage, the result being that the railroads now are largely increasing the track life of their ties, thereby reducing annual charges and in addition are able to use ties from timber not considered suitable previous to the development of the preservative treatment.

In 1911 the United States Census Bureau reported that the average tie renewals per mile of track in the United States for that year was 336. In 1921 renewals on the Boston & Maine Railroad averaged 270 per mile, while for the ten-year period ending this same year, the average was 278 per mile.

For the ten-year period from 1911 to 1920 inclusive, the average renewals on the New York New Haven & Hartford Railroad were 330 ties per mile, while

for 1921 their reports show 372 per mile.

Compared with these figures the following roads, on which preservative work has been in use for some years, reported as renewals for the year 1921 :

	Per mile.
Cleveland Cincinnati Chicago & St. Louis Railroad	80
New York Central Railroad	172
Rock Island Lines	169

The Atchison Topeka & Santa Fe Railway reported a reduction for ten-year period of 1904 to 1914 inclusive, from 261 to 179 tie renewals per year, or an annual saving of practically $700 000 in the purchase and installation of ties alone, this being particularly interesting to notice considering the material increase of ton mileage per mile of track during that same period.

The principal sources of ties at the present time in New England are :

a) Native chestnut : which supply, on account of the blight, will be commercially extinct in about three years;

b) Yellow pine : which is suitable for use without treatment, will cease shortly to be a commercial source of supply on account of depletion of yellow pine timber. For some years past it has been most difficult to obtain a suitable quality without paying exhorbitant prices;

c) Cedar : cedar ties, which are suitable for branch lines and sidings, and, while having a longer life than either the chestnut or pine, are not suitable at all for heavy main line use on account of being soft. It is undoubtedly a fact that cedar ties will be available for branch lines and siding use for an indefinite period.

This means that for New England other sources of supply for ties must be developed and the logical and conclusive source of such supply is from the woods available within our own states or within short haul thereof, where at the present time an almost unlimited supply of beech, birch and maple woods, which, while entirely unsuitable for ties without treatment, can, with proper treatment, be expected to last from fifteen to twenty years, and, as a matter of fact, we have records already along this line.

Specific information furnished by the engineer of maintenance of way of the New York Central Railroad in 1918 shows that during the previous four years the New York Central Railroad had used about 98 000 yellow or red birch ties, all treated with creosote, and that it was considered that while the life of such ties untreated would be only four years, they would last approximately twenty years with treatment, and this is being proved each year to be a fact.

The chief engineer of the Toronto Hamilton & Buffalo Railroad reported this same year that they had been using from 20 000 to 25 000 beech, birch and maple ties yearly, during the previous three years, all of which had been treated with creosote; and that while they considered the average life of such ties untreated to be approximately five years, they expected from twenty to twenty-five years from them as a result of the creosote treatment.

It is apparent, therefore, in New England, that the railroads are well warranted in taking up such treatment for obtaining ties for their future use. Based on present prices the cost of a beech, birch or maple tie creosoted is somewhat less than that of a yellow pine tie untreated; is about twice that of a chestnut tie untreated, while two creosoted ties will cost approximately the same as three cedar ties untreated.

When we realize that the treated ties will give from fifteen to twenty years' service, as compared with yellow pine ties lasting from six to eight years, chestnut ties lasting from seven to nine years, and cedar ties lasting from ten to twelve years, it can be readily seen that, compared with the present conditions in

New England, there is considerable economy in the use of treated ties, while under the conditions which we are now facing the economies will, of course, be much greater.

From careful studies made this year on the Boston & Maine Railroad, it was developed that by installing a creosoting plant and gradually increasing the use of beech, birch and maple treated ties from 400 000 the first year to 800 000 in the fifth year, the original investment would be returned to the railroad during this time, and beginning the fifth year, there would be a gradual decrease in tie renewals annually until at the end of the eighteenth year there would be a probable reduction in the annual renewals from 1 300 000 to 700 000 ties, with an ultimate annual saving in cost of tie renewals of approximately 1 million dollars per year. Undoubtedly such a plant will be installed in the near future.

During the present year the New York New Haven & Hartford Railroad has, under contract with the American Creosoting Company, erected a plant at Montewese, where they began in June the treatment of ties by creosote, using the Lowry process.

While records show a rapidly increasing use of treated ties few railroads have so far adopted treated lumber for general use, but it is to be expected before many years it will come into general use on all railroads; 1° because lumber is the most important material used in the bridge and building department and will probably not be displaced to any great extent by any other materials in the future; 2° on account of the rising cost of lumber the railroads cannot afford to use it untreated and allow it to decay in the structures as at present; and 3° on account of the increasing scarcity of the better grades which can be used untreated, it will become necessary to use the poorer grades which become suitable only after treatment.

One of the developments that will come about with the general use of treated timber is the framing of the timber before treatment, eliminating cutting in the field, that has caused so many failures in the past, and permitting the use of machinery instead of hand work in the framing of timber. As a result structures will be built with more care and with an expected life of from thirty to forty years rather than from six to fifteen years, as at present. Where railroads have used treated timbers in their bridges, docks and wharves to any extent, their reports, as issued, speak very highly of the benefits they are receiving from such use.

In closing I might add that there is now a tendency toward the use of creosoted timber in the construction of freight cars, records showing that decay, which could be very materially stopped by creosoting, is responsible for more than 80 % of the failure of car material.

[656 .253 (.73)]

Modern signals expedite heavy suburban traffic.

Figs. 1 to 4, pp. 265 and 267.

(*Railway Age.*)

Operation of the Lackawanna's suburban trains in the New York district has been facilitated by the adoption on the section of line most difficult to operate of advanced operating methods, made possible by the installation of a highly developed signal plant using color-light indications throughout.

The section where the measures for improvement were taken lies between the Hackensack and Passaic rivers on the road's Morristown branch, its heavy suburban line. Operating troubles, aside from those normally encountered in handling heavy traffic with a limited number of tracks, arise principally from the drawbridges over the Hackensack and Passaic rivers. Traffic in these rivers, particularly the former, is heavy and is increasing. With trains during the rush periods following each other at intervals of from one to five minutes, the opening of either drawbridge for a few minutes results in holding up perhaps as many as a dozen trains. The problem was to secure the greatest possible utilization of available running tracks as soon as the drawbridges were closed. Formerly trains so held up had to follow each other on one track, assuming again the space interval maintained by automatic block signals. Thus the opening of a drawbridge during the rush hour would cause delays to some trains much greater than the period of time when the draw was open.

The seriousness of the open drawbridge as a source of delay to trains can readily be understood when the company's figures of trains thus delayed are examined. In June 1922, a typical month, a total of 4 491 suburban trains were run. Of these 179 met with delays and the delay to 104 (58 %) of these was chargeable to open drawbridges. On at least two occasions in the past the road has joined with others in the attempt to secure a ruling to the effect that drawbridges need not be opened during rush hours. On both occasions, however, river shipping interests with powerful political influence were able to defeat the railroads' proposals. The result is that during almost any rush suburban hour may be seen the ludicrous spectacle of a tugboat towing a sand barge through a drawbrigde to the delay and inconvenience of thousands of passengers.

The increase in the Lackawanna's suburban passenger traffic has been very great in recent years. The road is now handling about 21 500 000 passengers a year at its Hoboken terminal and all but about 800 000 of these travel on suburban trains, by far the greater number of which move over the Morristown branch through Newark. Westbound through trains likewise move over this line, while eastbound through trains, a few suburban trains and practically all the road's freight trains move over the Boonton branch through Paterson. It is the line through Newark then, which has had to bear the brunt of the heavy increase in suburban traffic. Over this line are scheduled more than 160 passenger

Fig. 1. — Looking Eastward with Hackensack bridge in the distance. The three eastbound and two westbound signals show the two reversible tracks and the one non-reversible eastbound track. Train is westbound on No. 1 track (reversible).

Fig. 2. — Looking westward near Sanford's crossing. Strong green lights of reversible track westbound signals show white in illustration. In the distance two more signal bridges can be seen, showing the close spacing of signals.

trains a day. Most of these trains are of all-steel equipment and during the rush periods they run from eight to twelve cars. Superheated steam eight-wheel, ten-wheel and Pacific type locomotives are used, frequently double-headed. Originally a double track line, it had been increased to three tracks from Newark to Roseville avenue and from Orange to Millburn. The addition of a third track from Roseville avenue to Orange to connect these two three-track sections is now under way and, when completed will give the road nine miles of unbroken three-track line westward from Newark. From Hoboken terminal to West End tower, 1.9 miles, where the Boonton branch leaves the Morristown branch, there are four main tracks. It is on the line between West End tower and Newark, 5.9 miles, where the improvements described herein have been made.

The drawbridges over the Passaic and Hackensack rivers are double track. The section of line between these two bridges was also double track, and there was in addition a third track of light construction used for freight switching movements but not for passenger traffic. The first step taken to improve operating conditions was to rebuild this track applying heavier rail and rock ballast and making it available for passenger trains. The double track drawbridges were not altered, however, and no other track changes were made, with the exception of providing crossovers where needed. The company then had : 1° a four-track line from Hoboken terminal, 1.9 miles, to West End tower (which is just east of the Hackensack river); 2° a short double track line across the Hackensack river; 3° a three-track line from the Hackensack river to the Passaic river; 4° a short double-track line over the Passaic river to Newark, and 5° a three-track line from Newark west. The problem was to secure the greatest possible efficiency from the two double-track sections over the rivers and the three-track section between them, in order to clear away as rapidly as possible any congestion of traffic occasioned by the opening of a drawbridge and any normal congestion which might result by a reason of the two short double-track sections in a territory where three or four tracks have been found necessary to meet the demands of traffic.

Ordinarily where three running tracks are provided two of them may be used in one direction only and the third is reversible during certain hours of the day. The Lackawanna has improved upon this practice by making only one of its three tracks, *i. e.*, track, No. 2, between the rivers usable in one direction only, *viz.*, eastward. The other two tracks, No. 1 and No. 3, reversible, and not during certain hours of the day only but at all times. Furthermore, both of the two tracks over the rivers are reversible at all times. By the addition of this track the road has doubled the capacity of this section of its line, allowing for ten trains in a given direction where there was room for but five before.

Without the most modern signaling equipment, however, it would not be practicable to reverse the direction of traffic over a given track at any time during the day. Traffic levers, therefore, are provided in all the signal towers between Newark and West End tower to control the operation of the reversible tracks. The traffic lever must be set in proper position before a signalman can display a clear signal to a train on a reversible track and the signalman cannot place his lever in proper position unless the signalman in the next tower places his lever governing that section of track in the same position. This the second signalman cannot do until he has displayed the stop signal against opposing movement.

For example, take the rush period in the morning when the heaviest movement is eastbound. Assume that two

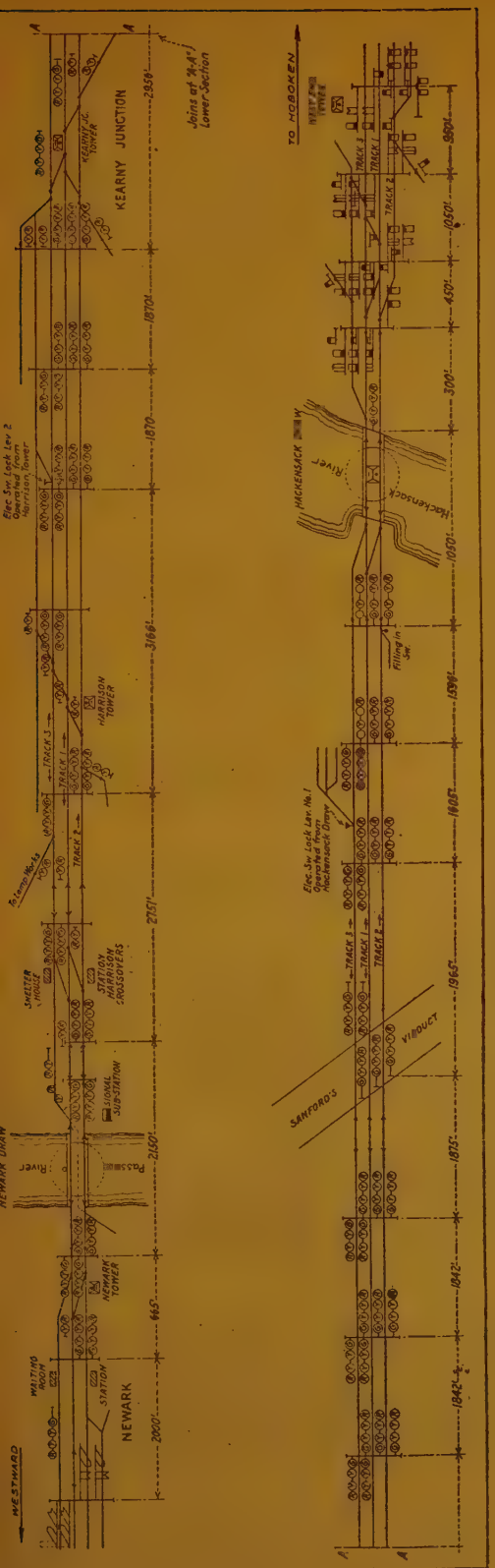


Fig. 4. — Diagram showing color light signals between West End and Newark. — Upper section joins lower at left.

eastbound trains arrive at Newark simultaneously, one on track No. 1 and the other on track No. 2. Naturally, during this period one of the two bridge tracks, *i. e.*, No. 2, will have its traffic levers set normally for eastbound movement, so one of the trains will naturally find the signals in position for its movement. The signalman, however, is aware of the approach of the second train and, let us assume, knows that no westbound trains are due. He will try to move his traffic lever governing track No. 1 to allow the second train to proceed over it. If the signalman at Harrison tower cooperates, sets his signal against opposing westward movement and moves his lever as desired, then the signalman at Newark can allow the second train, as well as the first, to proceed on its journey without delay, using track No. 1 over the bridge. Without the traffic lever, he would have to hold the second train until the first had departed and cleared the block on track No. 2.

Traffic levers are provided similarly to govern the two reversible tracks, Nos. 1 and 3, between Harrison tower and Kearney Junction, Kearney Junction and the Hackensack bridge tower and Hackensack bridge tower and West End tower. In practice there is not much frequency in reversing the direction of traffic except over the two drawbridges. Over the three track section one track, No. 2, is non-reversible eastbound. During the morning rush the traffic levers will be lined up to convert one of the reversible tracks, *i. e.*, No. 1, also to eastbound movement and the other (No. 3) to westbound. At the drawbridges one track will normally be lined up for eastbound and the other for westbound movement. Under normal conditions very little changing of traffic levers is necessary, except that governing one of each of the bridge tracks and to allow for freight switching movements over track No. 3. During the evening (westbound) rush both reversible tracks between the rivers

are lined up for westbound movement and eastbound traffic moves exclusively over No. 2, the non-reversible track. At the bridges, one track (No. 1) is lined up for west bound and one (No. 2) for eastbound movement and frequent shifting of levers will occur only for one of these tracks on each bridge when they are used, temporarily, for westbound trains.

In spite of the fact, however, that only at the bridges are changes in the direction of traffic sufficiently numerous to bring the levers into frequent use, the provision of them elsewhere makes for a flexibility of operation which in turn reduces to a minimum delays to following trains by derailment or by signal failures. If a reversible track is blocked for any cause, a signalman has only to shift the traffic lever for the remaining reversible track and following trains, crossing over, may proceed without delay.

The automatic signals in this territory are noteworthy. They, as well as the interlocking signals, are exclusively of the color-light type, using high voltage alternating current supplied by the company from its Hoboken power house, with a connection to the power lines of the Public Service Electric Company as an auxiliary source of supply. Fog and smoke often seriously obstruct vision in the Hackensack meadows and the color lights have a higher degree of visibility by either day or night than any other type of signal under these conditions. All interlocking plants in the territory are of the electro-pneumatic type of the latest design. Automatic block signals have four indications as follows :

Color given by	*Indication*
1. Red light over yellow light	Stop and proceed.
2. One yellow light	Approach next signal prepared to stop.
3. Yellow light over green light	Approach next signal at restricted speed.
4. One green light	Proceed.

The signals on these tracks are close together, a number of them being only about 1 800 feet apart. This, of course, makes for high track capacity. Furthermore, with four indications, high speeds when the clear indication is given are safer than where only three indications are provided. The engineman will pass two warning signals, allowing ample time for reducing speed, before he comes to a stop signal. The Lackawanna has, therefore, not only doubled the capacity of its line across the meadows by the addition of another running track — it has also made safe high rates of speed by the use of four-indication signals.

High interlocking signals have six indications, as follows :

Color given by	*Indication*
1. One red light	Stop.
2. Red light over yellow light	Proceed at slow speed prepared to stop.
3. One yellow light	Approach next signal prepared to stop.
4. Yellow light over green light	Approach next signal at restricted speed.
5. Red light over green light	Proceed at restricted speed.
6. One green light	Proceed.

Slow speed interlocking signals have two indications : One red light, indicating stop, and one yellow light indicating proceed at slow speed prepared to stop.

Telephones have been provided at all signal bridges and main line switches have been provided with electric switch locks controlled by towermen.

Officers of the company hold the new signal system and the results they are

obtaining from it in high regard. They report, too, that enginemen, although at first rather doubtful about the color-light signal, now are enthusiastic about it. The company is extending this form of signaling westward to Orange in connection with its extensive track elevation work at East Orange. When this work is completed, the company will have 9.4 miles of its line of heaviest traffic equipped exclusively with this type of signal.

[656 .223.2 (.73)]

How the Union Pacific keeps its freight cars moving.

Figs. 1 to 3, pp. 269 to 273.

(*Railway Review*)

One of the most conspicuous achievements in contemporary railway operation is the phenomenally high freight car mileage per car-day attained on the Union Pacific Railroad in response to the volume of traffic moving over that railroad. This record of operation contrasted with the average maintained on all Class I railroads over a number of years is illustrated in figure 1.

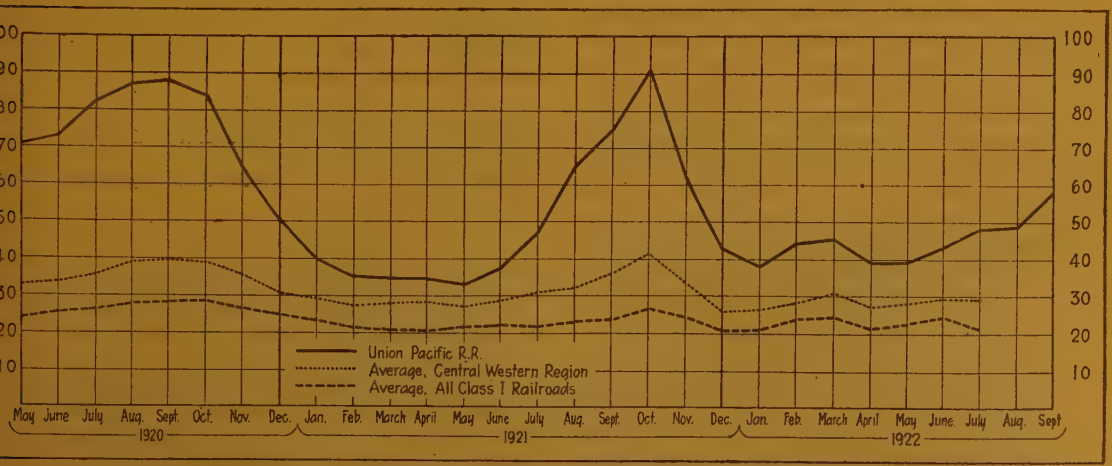


Fig. 1. — Car-miles per car-day on the Union Pacific Railroad, Average for all railroads in the Central Western Region and all Class I railroads.

In commenting upon this performance it is customary for those not intimately familiar with the situation, to overlook some of the policies fundamentally responsible for the high average car-mileage on this railroad. This has been variously ascribed to a heavy transcontinental movement embracing many high class commodities that require expeditious handling, to a low percentage of local

freight shipments, also to the physical features of the line which are admittedly favorable to fast freight train operation. Yet none of these factors would in themselves insure a high average mileage for all freight cars on line and as will be noted in another chart accompanying this article, the percentage of local freight originating on the Union Pacific is actually higher than the average on all Class I railroads. Probably the greatest advantage which this railroad enjoys over other roads in this respect lies in the relatively few large industrial terminals in proportion to the total mileage of the railroad.

The prompt movement of cars received from connections, on the other hand, rests largely with the management of the railroad since the physical characteristics of this property cannot be said to be materially better in this respect than some other double-track railroads. It is a reasonable presumption, therefore, that the real basis for this showing lies in the energetic execution of certain well defined policies and it is the chief purpose of this article to describe, so far as possible, operating methods directed toward the achievement of a high average car mileage on the Union Pacific.

The first factor ordinarily associated with car-miles per car day is the average train speed and, as the physical characteristics of the Union Pacific line are obviously favorable to the maintenance of high average freight train speeds, this is often regarded as the principal factor contributing to the high average car-mileage per car-day achieved on that railroad. While the Union Pacific takes full advantage of high average train speeds between terminals as a means for expediting car movement, an analysis of all the factors controlling freight car movement will demonstrate that a considerable increase in the speed of freight trains has only a minor effect upon the average daily mileage of all freight cars. This is clearly illustrated by the following figures which approximate the situation on the Union Pacific, where the average length of haul for a loaded car is 450 miles. As loaded car-miles constitute approximately 70 % of the total car-mileage, the average freight car-miles per shipment is 640. It is estimated that the average delay occasioned by repairs to freight cars on the Union Pacific is approximately 20 hours for each 640 miles run and it is assumed that time required for switching the car at terminals amounts to 24 hours for each shipment. Then, if the car is held for loading and unloading this shipment a total of 5 days, the distribution of time and mileage per day may be determined as follows for an average train speed of 10 and 16 miles per hour :

	Average speed of freight trains.	
	10 miles per hour.	16 miles per hour.
Loading and unloading shipment	120 hours	120 hours
Switching car at terminals.	24 —	24 —
Repairs to freight car per 640 miles	20 —	20 —
Time in trains per 640 miles.	64 —	40 —
Total time required per 640 car-miles	228 hours	204 hours
Average car-mileage per car-day	67.4	75.3

From the foregoing it will be observed that under these conditions, an increase in the average train speed of 60 % will only cause an increase of 12 % in the average car-mileage per car-day and that a loss of one day in unloading or in terminal delay will alone nullify the entire effect of increasing the average speed of freight trains from 10 to 16 miles per hour. In reality, therefore, the attainment of the high average freight train speeds shown in the accompanying chart is not so essential to increasing the average speed of freight car as to increasing the ability of the railroad to handle a large volume of freight. In this respect,

a uniformly high speed for all freight trains is vital to keeping the railroad clear at certain times of the year when from 30 to 40 freight trains are being regularly dispatched daily in each direction over the heaviest mountain grade sections of the Union Pacific. Over this portion of the line there are also eight passenger trains scheduled in each direction per day at an average speed of 36 miles per hour. The regularity of this movement is further emphasized by the fact that during the heaviest traffic movement it is not unusual to find a freight terminal yard on the main line practically clear of freight cars. In this operation, block signals play an important part. In fact, it would be admittedly difficult, if not impossible, to maintain this train movement without block signals even on a double track line with an abundance of motive power.

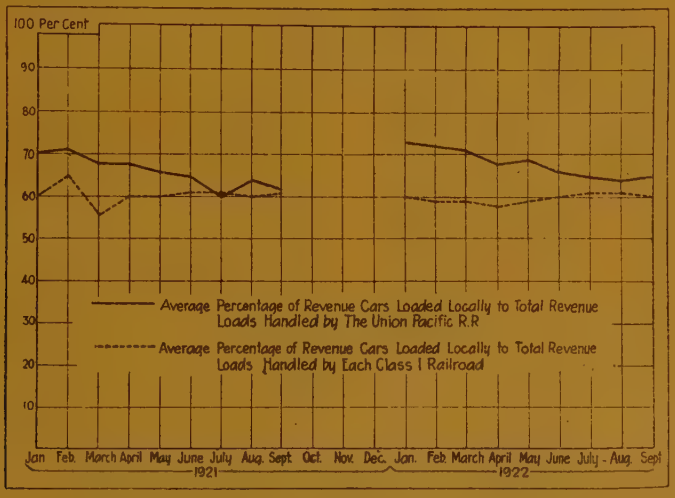

100 Per Cent
90
80
70
60
50
40
30
20
10
Average Percentage of Revenue Cars Loaded Locally to Total Revenue Loads Handled by The Union Pacific R.R
Average Percentage of Revenue Cars Loaded Locally to Total Revenue Loads Handled by Each Class I Railroad
Jan Feb March April May June July Aug. Sept Oct. Nov. Dec. Jan. Feb March April May June July - Aug. Sept
1921
1922

Fig. 2.

Turning to the more detailed features of this operation, a noticeable practice in connection with the high average mileage of freight cars on the Union Pacific, is the rapid handling of empty cars. Many roads are inclined to concentrate their attention on loaded cars and overlook the necessity for the equally prompt movement of empties if a high average speed is to be maintained. In fact, it is the tardy movement of empty cars and consequent accumulation at terminals that often impedes the quick movement of loaded cars. The best example of this feature on the Union Pacific is found in the movement of west bound empty fruit cars. During some months the average speed registered by empty refrigerator cars moving west over the Union Pacific has exceeded 300 miles per day. Recently all empty fruit cars on this railroad were moved an average of 330 miles per day for an entire month.

Another practice contributing to the expeditious movement of freight trains on the Union Pacific and System lines is that of picking up solid trains of coal and stock and running them through to destination without switching at intermediate terminals. While the Union Pacific would never be regarded as a coal road, it is pertinent to note that at two points alone on its main line in Wyoming, no less than 500 cars of coal ori-

ginate daily when conditions are normal. This coal is moved out from assembling points in the vicinity of the mines in solid train loads and empties returned in the same manner as ordinarily practiced by the large coal carrying railroads. Large shipments of live stock also originate at many points along the Union Pacific and System lines. Wherever practical, these shipments are moved to destination in solid train loads.

It has been stated that the commodities handled by the Union Pacific normally include a considerable proportion of high class transcontinental freight. The extent of this movement may be judged by the fact that the average length of freight car haul on the Union Pacific is approximately 450 miles, as previously referred to. This is taken advantage of in the form of manifest and through merchandise car movements executed in accordance with the same general plan as in effect on other railroads but with greater attention to the elimination of delays to manifest freight than is ordinarily observed. This check on delays to certain manifest freight not only covers the situation on the Union Pacific but is extended to include connecting carriers and a weekly statement is prepared to show not only the average hours delay per 10 000 loaded car-miles per manifest car on the Union Pacific Railroad but on each of the connections with whom this character of freight is exchanged. A typical report for manifest car movement on the line of the Union Pacific shows that out of one million loaded car-miles there was an average delay of 8.8 hours per 10 000 loaded car-miles. In this connection it is interesting to note that the Pacific Fruit Express Company's refrigerator cars average 40 % more miles per delay account bad order than the average of all other manifest cars. This showing is attributed very largely to the fact unusual care is exercised in the maintenance of these cars and that on each trip, prior to loading with fruit, they are all sent tot the shops in California for a careful inspection and needed repairs.

On any railroad, the rip track unquestionably presents a serious obstacle to the attainment of a high car-mileage per car day. Delays incident to rip track repairs are further aggravated on many railroads where the practice of making only such repairs, as will suffice to get the car off the rip track, is permitted. This situation is referred to because the policy of the Union Pacific with respect to freight car repairs is regarded as having an important bearing on the high average freight car mileage per car day attained on that railroad. Under normal conditions the average car mileage between rip track repairs on the Union Pacific is in excess of 2 500 miles, compared with an average freight car mileage on all roads of less than 1 000 miles between rip track repairs. It is instructive to note in this connection that approximately 15 % of all freight car repairs made by the Union Pacific Railroad are heavy repairs, whereas 10 % of the freight car repairs made by all roads are heavy repairs. Incidentally, it may be observed that aside from the gain in the average miles per day resulting from the greater mileage between rip track repairs, the railroad profits directly through a reduction in the switching expense incured in moving cars to and from the rip track. This may be safely estimated to be not less than six dollars for each movement to and from the rip track so that the Union Pacific spends only this amount while the average railroad is spending from $15 to $18, or about 30 % of the average cost of maintaining a freight car, in switching it to and from the rip track.

Another weekly report used to assist in expediting freight movement on the Union Pacific shows the volume of freight traffic and the proportion of east and west bound manifest excluding fruit and live stock, practically all of which is

east bound. This report shows the total number of manifest cars set out for cause and is followed by a very thorough analysis of the causes responsible for the cars being set out. The following is a typical example of such an analysis.

Transportation delays, percentage caused by :

	Per cent.
Awaiting movement and delivery	49.1
Account reducing tonnage	50.9
Weather	0.0
Accidents	0.0
	100.0

Mechanical delays, percentage caused by :

	Per cent.
Air brake cleaning	9.4
Brake rigging	12.6
Body and frame work	11.4
Draft rigging	20.5
Journals or hot box	19.3
Shifted load or over load	2.0
Transfer	3.2
Trucks	5.8
Wheels	15.8
	100.0

Normally, the average delay to manifest cars set out on the Union Pacific is less than 15 hours and reports involving over 7 000 manifest car movements on this railroad in which no cars set out incurred a delay of more than 48 hours, are typical. The most effective means employed to prevent extended delay to manifest cars that have been set out for any cause, is the strict enforcement of a rule requiring that where it is estimated that repairs to the set-out manifest will require 48 hours or more, the contents of the car be transferred immediately.

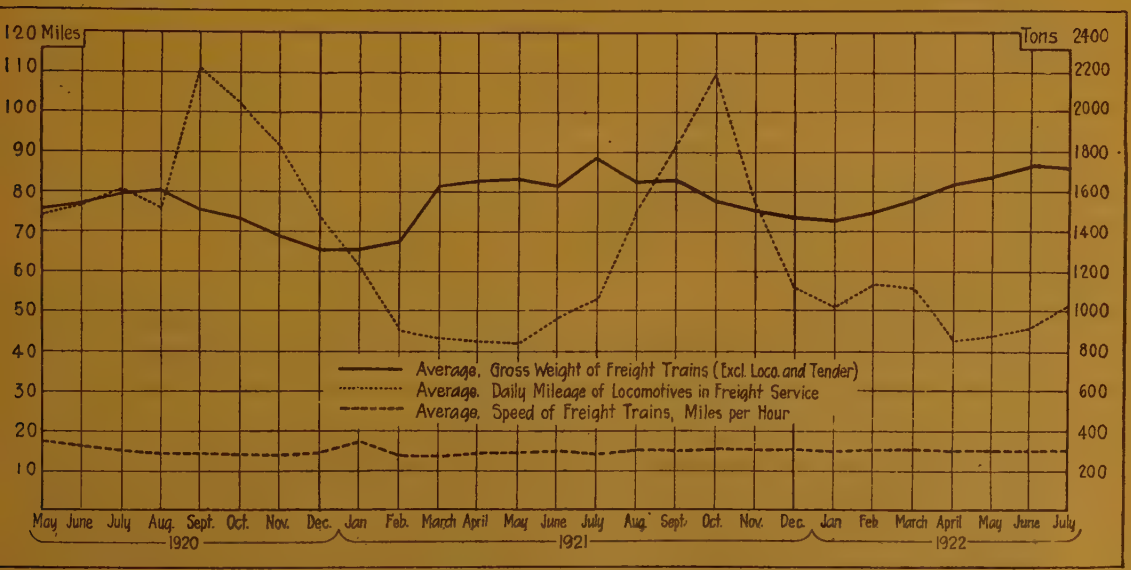


Fig. 3. — The average tonnage and speed of freight trains on the Union Pacific Railroad, together with the average daily mileage of freight locomotives on this railroad is shown in the above chart.

Knowing that any delay to a manifest car exceeding 48 hours will necessitate an explanation, those in charge of the situation must make certain that the car

can be repaired within 48 hours or proceed at once to transfer the load so that it will move forward within the 48 hour limit established by the management.

Dilatory handling and use of cars for storage rather than for transportation purposes by consignees and other abuses by shippers not only result in cutting down the average car-mileage per car-day as previously pointed out, but retard

Form 4630 — Standard R-9-20-100M

UNION PACIFIC SYSTEM

MAIL, OR WIRE SYMBOL (X) REPORT OF DIVERSIONS ACCOMPLISHED

SUPERINTENDENT OF TRANSPORTATION, OMAHA, NEB.
CAR SERVICE AGENT, SALT LAKE CITY, UTAH.
CAR SERVICE AGENT, PORTLAND, OREGON.
(Draw line through names not to be sent.)

Station.....
.....192.....

(*a*) File..... (*b*) As instructed by.....

diversion accomplished on (*c*) Car number and initial.....

(*d*) From..... (*f*) Billed to.....

(*g*) Diverted to..... (*h*) Via.....

(*j*) Date car arrived..... (*k*) Date car released and ordered forward.....

(*m*) Date forwarded..... (*n*) Days delay.....

As per Superintendent Transportation's Circular No. 35, paragraph 7, the following charges accruing under current tariffs were properly assessed :

(*q*) Reconsigning Charge..... $.....
(*s*) Inspection Charge..... $.....
(*u*) Switching Charge..... $.....
(*v*) Demurrage Charge..... $.....
(*w*) Penalty Charge..... $.....

My File No.....; (Signed).....
AGENT.

Note : To facilitate handling of reconsignments or diversions it is important that full and prompt reports as above outlined be made.

Unless specifically requested in instructions to advise by wire, the report should be mailed and carbon copy retained for Agent's file.

Form used by the Union Pacific Railroad in connection with freight car diversions.

the whole transportation machine and for this reason the Union Pacific have found it necessary during periods of heavy demand to adopt drastic measures to enforce the prompt release of equipment by consignees, in order to thereby better serve the public.

The first step in this procedure is to require every agent to make a daily telegraphic report to the superintendent of transportation, of all cars that have been on hand, for unloading or disposition, four days or more. Upon receipt of this information the superintendent of transportation immediately wires the consignee appraising him of the heavy de-

mand and the necessity for prompt release of the equipment. Failing to receive a satisfactory reply or explanation for the delay, that provision in the standard bill of lading which gives the railroad the privilege of unloading and storing the contents of the car, at the consignee's expense is then invoked and the car is unloaded or moved to the nearest point at which the lading can be properly stored. In some instances the railroad has felt justified in moving cars 50 or 60 miles at its own expense in order to find a suitable place in which to store the lading and release the equipment for service, the cost of this haul being small compared to the value to its patrons of having the car available for useful service.

That the steps initiated by the Union Pacific have proved highly effective is evidenced by a comparison between the month of March 1922, when the average delay to cars held more than four days was only 5.9 days, while in March 1921, this average delay amounted to 8.2 days. The success of this policy, however, was contingent upon a correspondingly prompt movement of all cars immediately following their release. Not only is the actual movement of these cars essential to maintaining a high average car mileage per car day but the moral effect of neglecting to move a car promptly after the shipper or consignee had been urged to handle these cars as quickly as possible would obviously be disastrous to the successful execution of this program. As a consequence, it was found that plenty of switching power, not only for yard work, but for industrial track switching, was another requisite to the attainment of a high car mileage per car day on the Union Pacific Railroad.

Another detail in the management of the car situation on the Union Pacific that has an important effect toward keeping cars moving, relates to the diversion of freight cars. On this road, many diversions are arranged through the commercial agents who have the manifest reports. This enables the diversion to be handled directly and without delay, the action of the agent being subject to check by means of a subsequent report of diversions accomplished. This report is addressed to the Superintendent of Transportation but is later referred to the Auditor, who reviews the charges assessed for reconsigning, inspection, switching, demurrage, etc. By this method the average diversion of non-perishable shipments on the Union Pacific System does not involve, on the average, more than three telegraphic messages and is being accomplished with an average delay per car on account of diversion of approximately 26 hours.

From the foregoing it will be seen that the accomplishment of a high car mileage per car-day on the Union Pacific, while undoubtedly promoted by the favorable physical characteristics and traffic conditions on this railroad, is also due in no small measure to operating methods that could be just as effectively applied toward the same objective on other railroads. In the case of the Union Pacific, however, it has been shown that the attainment of the greatest possible mileage per freight car-day is not only essential to efficient operation but vital to the successful management of this railroad. The Union Pacific is strategically located to handle a large volume of freight from a number of connecting carriers at either end of its line, and must move this tonnage on a double track line over severe mountain grades. There are no large intermediate terminals serving as reservoirs for delayed cars so that the entire railroad must function at uniformly high speed. Under these circumstances, contrast a movement of 20 or even 30 car miles per car day, which is regarded as a good average on many railroads with the usual performance on the Union Pacific and consider the probable effect on this road of slowing down the car mileage to the average speed report-

ed for all class I railroads. The most obvious effect of this reduction in car-mileage per car-day would be an immediate increase in the number of cars required to handle the same traffic. Most of this increased car supply would be found in yards and sidings since an increase in the number of cars actually moving at any time would be accompanied by a corresponding increase in the number of trains and the capacity of the railroad in this direction would soon be reached. Therefore, the ultimate result of a slower car movement would be a reduction in the maximum capacity of this railroad or the construction of additional main line and terminal trackage. In either case, the cost of operation per revenue ton-mile would be greatly increased except when the traffic movement was very light. At this time, however, a reduction in car-miles per car-day would increase per diem payments to the extent that this reduction in speed affected the movement of foreign railway equipment.

For the country as a whole, car-miles per car-day is simply a function of the number of cars owned and the traffic handled so that the average daily mileage must necessarily fluctuate with the total volume of freight moved and when business is light, the average car-miles per car-day will necessarily be lower than at times when traffic is active. Under these conditions, a reduction in car-mileage per car-day does not indicate inefficient operation. At such times, a reduction in the average car-mileage may actually be desirable. It is the ability of the railroad to respond to heavy traffic increases with a higher daily car-mileage that indicates the greatest efficiency in this direction and when freight traffic is heavy throughout the country it is the duty of all railroads to keep freight cars moving as rapidly as possible. Then the number of cars required to handle the business or the amount of business that can be handled with the available cars is directly proportional to the average daily mileage of all freight cars.

Speeding car movement on a railroad is therefore equivalent to speeding production in a factory, and the transportation officials who are devising means to expedite the movement of freight cars are as truly production engineers as those who specialize upon the production of any factory product.

MISCELLANEOUS INFORMATION

[625 .112 (.3)]

1. — Many gages are found throughout the world.

(*Railway Age.*)

Notwithstanding the general tendency throughout the world toward uniformity in railway details, and especially in the promotion of free inter-communication, there is one important detail with respect to which there is still a lack of universal agreement. That detail is the railway gage. The accompanying statistics of railway mileage by gages, compiled by the Bureau of Railway Economics for 59 of the principal countries of the world, show that no one gage or width of track has been adopted to the exclusion of others; the majority of the railways, however, use the so-called « standard » gage of 4 ft. 8 1/2 in. This gage is practically universal in the United States, Canada, Cuba, Holland, Hungary, New South Wales, Turkey and Chosen.

Next to the standard gage comes the meter gage of 3 ft. 3 3/8. in. This is the almost exclusive gage in Porto Rico, French Sudan, Malay Peninsula, Bolivia, and Dutch Guiana, applies to a large part of the mileage in Brazil, and is found on some mileage in nearly all the principal countries of Europe and Asia. The two next important gages in use seem to be the 5 ft. 6 in. gage and the 3 ft. 6 in. gage. The former is found chiefly in India, Spain and Argentina. The latter is standard in South Africa, New Zealand, South Australia, Queensland, Tasmania, Western Australia, Japan, and the Philippines.

The accompanying tabulation gives details as to gages on 565 088 miles of railway in the 59 countries. These 565 088 miles represent about 76 % of the total railway mileage of the world. Several important, and a number of unimportant, countries are not included because complete or up-to-date statistics are not easily available. Among the countries so excluded are Russia (including Siberia), Germany, Poland, Turkey in Europe, Bulgaria, the Balkans, and various possessions in Africa and elsewhere.

NORTH AMERICA.

Gage.	Canada.	Mexico.	United States (1)
4 ft. 9 in.	...	...	190
4 ft. 8 1/2 in. . . .	35 694	10 286	241 938
3 ft. 6 in.	904	...	...
3 ft. 3 3/8 in. . . .	...	16	...
3 ft. 0 in.	...	1 848	1 285
2 ft. 6 in.	...	33	...
2 ft. 0 in.	...	21	...
Total. . .	36 598	12 204	243 413

Source: Reports of the carriers to the Interstate Commerce Commission and the Universal Directory of Railway officials. — (1) Miles of main track owned.

CENTRAL AMERICA.

Gage.	Costa Rica.	Guatemala.	Nicaragua.	Panama.	Salvador.
5 ft. 0 in.	...	...	...	53	...
3 ft. 6 in.	322	...	166	...	...
3 ft. 0 in.	...	962	...	...	100
Total. . .	322	962	166	53	100

WEST INDIES.

Gage	Cuba.	Jamaica.	Porto Rico.	San Domingo.
4 ft. 8 1/2 in. .	2 287	198	13	...
3 ft. 3 3/8 in. .	...	...	325	...
3 ft. 0 in. . . .	51	...	...	...
2 ft. 6 in. . . .	...	...	...	62
Total. . .	2 338	198	338	62

SOUTH AMERICA.

Gage.	Argentine Republic.	Brazil.	Chili.	British Guiana.	Bolivia.	Colombia.	Dutch Guiana.	Ecuador.	Paraguay.	Peru.	Uruguay.	Venezuela.
5 ft. 6 in.	14 356	...	64	...	...	.	...	...	...	..	...	...
5 ft. 5 in.	...	...	670	...	...	...	...	...	...	...	..	...
5 ft. 4 3/4 in.	..	...	11	...	...	...	...	...	.	...	...	...
5 ft. 2 1/2 in.	...	1 023	...	...	...	...	...	...	...	...	...	...
4 ft. 8 1/2 in.	1 793	8	431	61	...	...	...	...	158	1 016	1 557	...
4 ft. 3 1/2 in.	...	6	...	...	...	...	...	...	...	...	...	...
4 ft. 2 in.	...	..	79	...	...	...	...	...	...	...	...	...
3 ft. 6 in.	...	...	275	19	...	11	...	288	...	16	...	200
3 ft. 3 3/8 in.	7 337	18 987	1 497	...	358	345	108	...	..	73	...	48
3 ft. 0 in.	...	...	...	...	...	577	...	...	..	306	...	23
2 ft. 6 in.	...	454	784	...	...	..	...	...	...	...	...	...
2 ft. 5 17/32 in.	102	...	...	...	...	...	...	...	...	...	...	...
2 ft. 0 in.	..	...	...	...	...	...	...	...	...	...	...	136
1 ft. 11 5/8 in.	...	1 152	38	...	...	...	...	...	...	50	...	...
Total. . .	23 588	21 630	3 840	80	358	933	108	288	158	1 461	1 557	407

EUROPE.

Gage.	Belgium.	France.	Greece.	Holland.	Hungary.	Italy.	Luxembourg.	Norway.	Spain.	Sweden.	Switzerland.	United Kingdom.
5 ft. 3 in.	...	...	...	...	...	...	...	...	4 777	...	...	3 109
4 ft. 8 1/2 in.	2 972	27 602	780	2 604	11 854	11 518	198	1 297	58	5 863	4 003	20 070
4 ft. 6 in.	...	...	...	...	...	...	...	...	...	...	..	4
4 ft. 0 in.	...	...	...	...	...	...	...	...	...	...	..	7
3 ft. 8 in.	...	...	...	..	...	...	...	...	14	...	...	...
3 ft. 7 in.	...	...	...	...	...	...	..	...	...	51	...	...
3 ft. 6 in.	306	...	...	...	339	...	...	652	...	329	...	26
3 ft. 3 3/8 in.	2 128	4 308	639	...	30	214	312	16	3 644	...	608	...
3 ft. 1 9/16 in.	...	...	...	...	...	1 137	...	...	...	...	...	...
3 ft. 0 in.	...	...	...	...	..	...	...	...	...	...	..	395
2 ft. 11 in.	...	...	...	...	..	...	...	...	...	1 540	...	...
2 ft. 8 1/2 in.	...	...	...	...	...	...	...	...	...	...	...	2
2 ft. 7 31/32 in.	...	...	...	...	...	...	...	...	...	...	35	...
2 ft. 7 1/2 in.	...	...	...	...	...	...	...	..	...	32	...	5
2 ft. 6 in.	...	...	...	...	...	...	...	...	...	...	...	12
2 ft. 5 17/32 in.	...	...	...	...	9	...	...	52	65	...	9	...
2 ft. 4 1/2 in.	...	...	...	...	..	...	...	...	...	...	..	9
2 ft. 4 in.	...	...	...	...	...	...	...	...	...	...	...	3
2 ft. 3 9/16 in.	...	...	...	...	...	..	165	...	...	...	...	...
2 ft. 3 in.	...	...	...	...	...	...	...	...	...	...	...	24
1 ft. 11 5/8 in.	...	...	...	...	...	...	...	...	...	83	...	...
1 ft. 11 1/2 in.	...	140	...	...	...	...	...	...	...	...	..	51
1 ft. 3 in.	...	...	...	...	...	...	...	...	...	...	...	7
Total. . .	5 406	32 050	1 419	2 604	12 232	12 869	675	2 017	8 558	7 898	4 655	23 724

AFRICA.

Gage.	British East Africa.	Egypt.	French Sudan.	Gold Coast.	Nigeria.	Union of South Africa.	West Africa. (Angola).
4 ft. 8 1/2 in.	...	1 849	...	...	...	...	...
3 ft. 6 in.	...	1 070	...	269	983	8 982	390
3 ft. 3 3/8 in.	94	...	1 186	...	...	...	226
2 ft. 7 31/32 in.	...	...	...	...	...	560	...
2 ft. 6 in.	108	...	...	...	143	...	...
2 ft. 5 17/32 in.	...	915	...	...	...	...	...
Total. . .	202	3 834	1 186	269	1 126	9 542	616

AUSTRALIA.

Gage.	New South Wales.	New Zealand.	South Australia.	Tasmania.	Victoria.	Western Australia.	Queensland.
5 ft. 3 in.	...	...	1 124	...	4 092	...	...
4 ft. 8 1/2 in.	5 048	...	...	...	...	...	...
3 ft. 6 in.	36	3 010	1 210	818	...	4 003	5 931
3 ft. 3 3/8 in.	18	...	...	...	..	...	...
2 ft. 6 in.	...	...	...	...	122	...	...
2 ft. 0 in.	...	...	...	41	...	...	...
Total. . .	5 102	3 010	2 334	859	4 214	4 003	5 931

ASIA.

Gage.	China.	Chosen.	India.	Japan.	Malay Peninsula.	Mesopotamia.	Philippine Islands.	Siam.	Turkey.
5 ft. 6 in.	...	...	21 126	...	...	...	...	...	...
5 ft. 0 in.	3 746	...	...	...	...	...	...	...	...
4 ft. 9 in.	344	...	...	...	...	...	...	...	...
4 ft. 8 1/2 in.	2 242	1 157	...	24	...	186	...	590	814
3 ft. 6 in.	...	...	...	7 248	...	...	925	...	...
3 ft. 3 3/8 in.	151	...	13 914	...	1 209	624	...	836	...
2 ft. 6 in.	...	...	1 629	151	...	58	...	...	...
2 ft. 0 in.	...	...	582	26	...	...	...	...	...
Total. . .	6 483	1 157	37 251	7 449	1 209	868	925	1 426	814

Of the 565 088 miles operated in the 59 countries, here covered, in 1920, 396 169 miles are of the standard gage, 54 685 miles are of a gage wider than standard, and 114 234 miles of a narrower gage, the percentages being as follows :

Standard gage	70 %
Wide gage	10 %
Narrow gage.	20 %

The three gages shown for the United States are for the Class I railways, and represent 243 413 miles of main track owned. Practically all of this mileage is 4 ft. 8 1/2 in. gage. During recent years there has been a rapid concentration on the standard gage in the United States and at the present time only three gages are in use on Class I railways. Of these the standard gage represents

99.4 % of the total mileage, the remaining 0.6 % being divided between 4 ft. 9 in. and 3 feet.

The railway mileage of Canada is divided between two gages. 98 % represents standard gage, while the other 2 % is 3 ft. 6 in. gage.

The United Kingdom has 3 109 miles of the broad gage of 5 ft. 3 in. (1 m. 676), and it also boasts of the narrowest, that 1 ft. 3 in. However, 85 % of the railway mileage of that country is standard gage.

On the continent of Europe the English standards and details were adopted in the first lines to be constructed, and at the present time the standard gage, whose metric equivalent is 1 m. 435 represents 76 % of the railway mileage operated. But as in the United Kingdom this gage is not universal. For the 11 continental European countries shown in the accompanying statement no less than 23 gages are represented. Nearly all European countries (Spain excepted) have adopted the standard gage for their main lines, while secondary or local lines have been constructed on narrow gages.

In Africa the gages are mainly 3 ft. 6 in., 3 ft. 3 3/8 in. (meter) and 2 ft. 5 17/32 in. (0 m. 75). The railways there also operate 1 849 miles of standard gage.

The mileage of the railways of Australia, including Tasmania, consist of six gages. The 3 ft. 6 in. gage predominates with standard gage next in importance, while there is a small amount of mileage of 2 ft. 6 in., and 2 feet gages still in service. A commission recently appointed to consider the unification of railway gages in Australia has recommended that the 4 ft. 8 1/2 in. gage be adopted as standard.

In Asia, the Indian railways, the largest Asiatic system, are divided chiefly between a « broad » gage of 5 ft. 6 in. and a narrow gage of 2 feet. The greater percentage of the Chinese railway mileage is 5 feet, although 35 % of the mileage of that country is of standard gage. Practically all the Japanese lines use the gage of 3 ft. 6 in. (1 m. 067).

In South America there is great diversity, lines being built to gages ranging from 1 ft. 11 5/8 in. (0 m. 60) to 5 ft. 6 in. In Central America and the West Indies the principal gages are 4 ft. 8 1/2 in., 3 ft. 6 in., and 3 feet, with 4 ft. 8 1/2 in. predominating except in Panama, where the gage is 5 feet.

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[691]

2. — Protecting steel bridges from locomotive blast.

Figs. 1 to 4, pp. 281 and 282.

(*Engineering News-Record.*)

How to protect the underside of steel bridges exposed to blast, smoke and gases from locomotives is an important and often troublesome problem in large cities where numerous bridges have a limited headroom over tracks carrying heavy traffic. The resistance of different methods of protection applied to some Chicago bridges is shown in the accompanying views. The results are comparable, as the clearance in all cases is about 17 feet from the top of rail to underside of bridge.

In figure 1 is shown part of the underside of the bridge carrying the Chicago, Rock Island & Pacific Railway over the Chicago & Eastern Illinois Railroad at 79th Street. This is a gunite ceiling placed in 1914 by the Cement-Gun Construction Co., Chicago, under the direction of R. H. Ford, track elevation engineer (and now assistant chief engineer) of the former road. This view shows a portion of an expansion joint at a point where the engine blast is continuous and heavy. The white streak indicates where the blast has blown the surface clean of soot, but it will be noticed that the original pebbled surface is still intact and that even the corners of the expansion joint have not been rounded off in nine years of service.

Bridges over the tracks approaching the Chicago union station from both north and

Fig. 1. — Gunite ceiling of 79th street bridge.

Surface uninjured after nine years' exposure to locomotive blast.

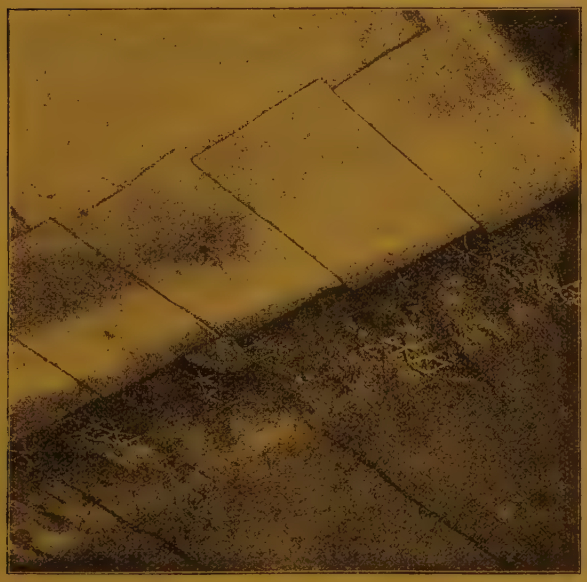

Fig. 2. — Effect of blast on concrete casing.

Condition after one year's exposure, with track center off center of blast plates, causing wear shown. Taylor street bridge.

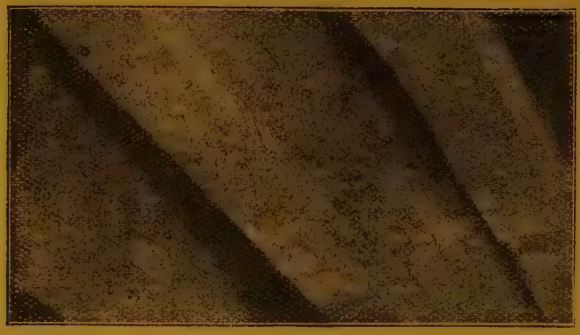

Fig. 3. — Blast near on concrete under slab.

Cast iron plates are on underside of beams. Taylor street bridge.

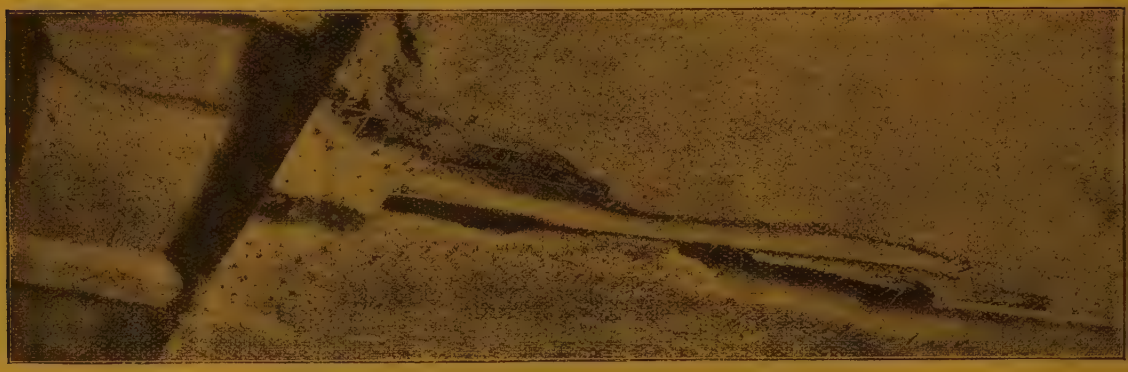

Fig. 4. — Concrete casing under Lake street bridge.

Condition after six years' exposure.

south afford examples of the service of various forms of steel protection under conditions of minimum headroom and heavy blast. Figure 4 shows the girders and floorbeams of the Lake St. bridge, which were encased in concrete poured at the same time as the floor. This work was done in 1915 and so the concrete has been subjected to about eight years of service. The 3-inch concrete under the main girders has been worn away, exposing the steel, and at the right of this a hole has been worn through the 3-inch ceiling. The ends of the broken steel reinforcement are shown, and at the extreme right is an exposed reinforcing rod. The sidewalk slab at the left is badly cut, and beyond the part shown in the view some of the bars are exposed.

The underside of the Taylor St. bridge, built in 1920-1921, is shown in figure 2. Poured concrete was used for the steel encasement, with cast-iron blast plates over the tracks. At the time the photograph was taken the track had not been placed in final position, with its center line directly under the iron plates, so that part of the blast has been received by the concrete. In one year of service the concrete, both where subjected to the center of the blast and at the sides of the

cast-iron blast plates which were not struck centrally, has been cut away so as to expose the reinforcing mesh. Figure 3 shows the same bridge where the floor structure is of a different type and where blast plates were placed on the concrete encasement of beams. Here also the concrete shows evidence of disintegration on the bottoms and sides of beams and the bottom of the floor slab.

At the Harrison St. brigde, two blocks north of the Taylor St. bridge and built at the same time, the main girders and beams were encased in gunite, while some of the smaller floorbeams were encased in ordinary concrete, poured at the same time as the slab. Blast plates were embedded in the gunite on the underside of the main beams and girders. This gunite casing shows no signs of deterioration, but is in the same condition as that on the 79th Street bridge shown in figure 1. Poured concrete casing of the floor beams and the concrete slab, although at a higher elevation above the track, are showing evidence of pitting and deterioration.

Although gunite for the protection of steel is approved by engineers of the lines described, some conditions are noted as necessary to successful results. Surfaces to be covered must be clean free from grease and dirt, the sand must be clean and suitable for cement-gun work, and the staging and apparatus must permit ready access to all parts and application of the gunite perpendicularly to the surface. Fresh surface must be disturbed as little as possible, the entire coating being applied as nearly as possible monolithic. The final surface. Fresh surfaces must be disturbed as little flat, edges straight and corners well formed. In order to accomplish this and to get maximum density and hardness, with absence of sand pockets, it is necessary to have the work done by experienced operators and foremen.

In some recent work where a concrete floor slab is used this slab encases the tops of the beams, the lower parts being then covered with gunite. It is considered questionable whether iron blast plates are necessary or desirable with gunite. The attachment of the plates to insure that their supports will not be destroyed introduces difficulties and the results at the 79th Street bridge seem to indicate that gunite alone is sufficient.

Experience with the Chicago bridges points to the following conclusions: 1° that with a headroom of 17 feet from the track a gunite casing properly applied will resist locomotive blast for at least nine years without injury; 2° that blast plates may not be necessary if gunite casing is used; 3° that plain concrete in such positions and with limited head room is not likely to form durable protection. The photographs were furnished by the Cement-Gun Construction Co., Chicago.

[621 .335 (.42)]

3. — Electric locomotive for passenger trains : North Eastern Railway.

Fig. 5 p. 284.

The North Eastern Railway has constructed at its works at Darlington an electric locomotive — 4-6-4 type — for passenger train work, and the principal dimensions are given in the *Engineer*.

The locomotive is constructed for 1 500 volts continuous current, thus falling in with the recommandations of the Committee appointed by the Ministry of Transport. It has been designed with a view of drawing a train of 450 tons at a speed of 65 miles per hour.

The electrical equipment which has been furnished by the Metropolitan-Vickers Company consists of three twin-armature motors mounted in the frames, one driving each axle. Contrary to the most usual practice on the Continent, connecting rods are dispensed with. Motion is communicated from the motor through reduction gearing to a hollow shaft or « quill » carried on the frames and encircling the axle. This shaft has an internal diameter sufficient to allow for the play of

the axles and is connected to the motor wheels by means of helical springs. The non-sprung weight is thus solely the wheels and axles.

The locomotive weighs 102 tons, of which the adhesive weight is 55.5 tons. The motors can develop 1 800 H. P. for one hour at a speed of 43 miles per hour, the tractive effort being 15 900 lb. 1 260 H. P. can be developed continuously at a speed of 51.5 miles per hour, the tractive effort being 9 480 lb.

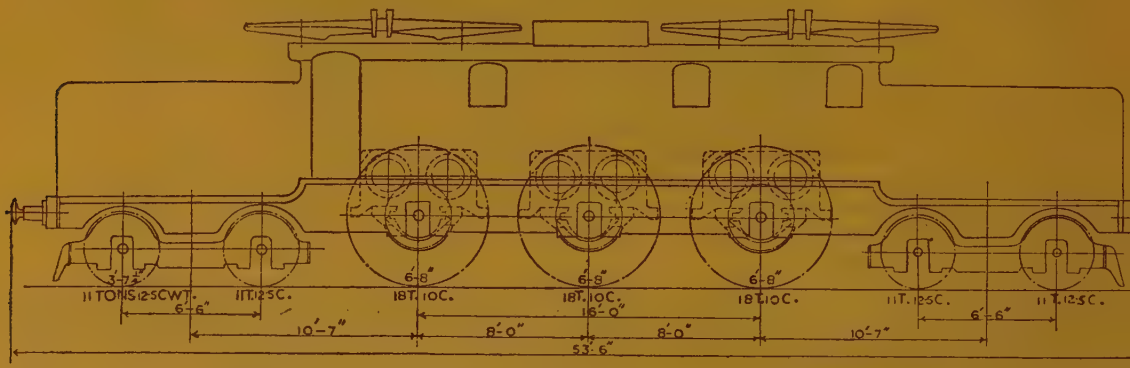

Fig. 5. — Electric locomotive for passenger trains : North Eastern Railway.

Current is taken from the trolley wire by two pantographs placed on the roof at each end to the central compartment, of which the two compartments at each end of the locomotive over the bogies are a continuation. One of these compartments contains the high tension apparatus, whilst in the other is fixed an electric heated boiler for furnishing steam for heating the train.

The advantages of this « quill » drive type of locomotive have also been dealt with by Sir Vincent L. Raven, Chief Mechanical Engineer of the North Eastern Railway, in a paper read before the Institution of Mechanical Engineers (1).

The dead weight on the road is reduced to a minimum, the motors forming part of the suspended load. The reduction by gearing allows of the motors being designed for a peripheral speed allowing of the maximum use being got out of the material. In addition, the centre of gravity is reasonably high owing to the use of driving wheels of large diameter and the placing of the motors above the axles. In the North Eastern locomotive the driving wheels are 80 inches in diameter, the dead weight per axle being 4.75 tons, and the peripheral speed of the armatures at a vehicle speed of 75 miles per hour being 5 560 feet per minute.

Two other main methods of transmission are so far employed with high speed electric locomotives. The one type consists of mounting the motor armature on the axle itself, it being capable of vertical movement between the poles which are fixed to the frame. In the other type the motors are placed high, whilst cranks at the end of the shafts are coupled by means of rods to a jack shaft which in its turn is connected by coupling rods to the driving axles. With regard to the first, Sir Vincent L. Raven states that the electric equipment is extremely simple as there are no special armature shafts, gearing or special bearings. These advantages tend to compensate for the higher cost of the motors themselves which, because of their low peripheral speed, are comparatively expensive. The second type he states has already been shown, with certain goods locomotives, to have inherent faults due to the use of coupling rods. With express locomotives, one may, owing to

(1) *Proceedings of the Institution of Mechanical Engineers*, No. 4, 1922.

the high speed, obtain a satisfactory peripheral velocity for the motors without having recourse to gearing. This however can only be done by using driving wheels of small diameter which must revolve at a higher speed than is common practice with steam locomotives.

The North Eastern locomotive is provided, as stated above, with a boiler heated directly by continuous current at 1 500 volts. With alternating current it is easy to step down to any desired voltage by means of a static transformer. To have stepped down with continuous current would have required a 300 kilowatt motor generator which would have been an unwelcome addition to the equipment.

The boiler is of the fire tube type, each tube containing a heating element consisting of a quartz tube, in the interior of which is a spiral of high resistance wire. The boiler contains 144 of these elements, and switchgear allows of the number of elements in circuit being reduced when it is not necessary for the boiler to give full output. The maximum output is about 1 000 lb. of steam per hour at a pressure of 120 lb. per square inch.

As will be seen from the outline of the locomotive (fig. 5) the wheels are placed symmetrically about the centre of the locomotive. In the United States experiments have seemed to show that a locomotive of such a symmetrical type is liable at high speeds to set up dangerous oscillations. American engineers have in consequence proposed a construction which, whilst symmetrical, when considered as a whole, is unsymmetrical as regards each part such as 4-6-0 + 0-6-4. These experiments have not up to the present been explained, and it may be that a special cause for disturbance exists in America owing to the staggering of the rail joints. In Europe there are in existence several steam locomotives having symmetrical wheel arrangement which give every satisfaction in as far as stability is concerned at high speeds, notably the 4-6-4 type of the Northern Railway of France, the 4-6-4 of the London Brighton & South Coast and the 4-4-4 of the North Eastern Railway.

[621 .135.2]

4. — Flange oilers reduce rail and tire wear.

Figs. 6 to 9, p. 287.

(*Railway Review.*)

The excessive flange wear on our locomotives and cars and the rail wear, especially on curves together with the derailments attributed to flange friction, has been a very annoying question to the various railroads for years. To overcome this friction, the following devices have been designed :

1. A piece of waste attached to the frame of the locomotive with a piece of wire in a position so that it would come in contact with the driver wheel flange. When the engineer was oiling around, he would drop some oil onto the waste, a small portion of which would reach the flange. The crudeness of this method was wasteful in the use of oil but some small benefit was derived;

2. The next advance was a crude tin can mounted on a bracket attached to the locomotive frame. From this can a pipe with a wick in the end was projected to a position over the driver wheel flange. After the can had been filled with black oil, the wicking was supposed to form a circuit between the oil in the can and the driver wheel flange. This helped a little, but in the majority of cases this caused the driving wheels to slip to such an extent that the method was impracticable;

3. From the above devices an arrangement was made with a flexibly mounted shoe that was supposed to be in contact with the flange. The use of this flexible shoe developed two noticeable facts : It was hard to keep the shoe in position and the oil was carried on the tread due to the lateral motion;

4. A stick of graphite held by a clamp from the frame in such a position as to rub on the

flange. The same difficulty was experienced as with the flexible shoe;

5. A reservoir of oil with a needle point resting against the flange and closed except when the wheels were working laterally. The slightest move laterally opened a valve and allowed the oil to run on the flange;

6. Hard grease to bear against the flange; but with this scheme the hard grease gathered dirt and sand and made an abrasive, causing rapid flange wear;

7. An oil receptacle with a pin valve fastened to a pendulum that was actuated by the motion of the locomotive and allowed the oil to be dropped on the flange;

8. An oil receptacle with the exhaust steam from the compressor forcing oil through a jet onto the flange. The exhaust steam from the compressor without any oil other than that used for lubrication of steam end of air compressor was tried, but without success;

9. In 1904 the hydrostatic oil lubricator, so termed because it works on the condensation displacement principle, was developed, and it has been generally conceded from previous tests that a successful flange lubricator is one that can be operated or controlled from the cab of the locomotive, and can be started or stopped at the will or judgment of the engineer. This is correct as far as it goes, but it stops just short of the ideal flange oiler. The engineers and firemen of our large modern locomotives have too many other duties to perform, and it would be impracticable to add another device for them to operate. Therefore an automatic oiler with a feed that would vary with the speed, or could be shut off at the will or judgment of the engineer, would be the practical oiler.

Let us assume that we have before us a section of a locomotive driver wheel tire that has the flange and tread in perfect contour. It is an established fact that by removing 1-32 inch from the throat of the flange, 1-16 inch metal would have to be removed from the tread of the wheel to restore contour, or 1/8 inch from the throat equals 1/4 inch from tread. On many railroads this represents considerable mileage lost. If this expense could be eliminated the cost of maintenance per locomotive mile would be greatly reduced.

When consideration is given to the heavy power, the high speed and the many sharp curves, the wonder is how small flanges will keep locomotives and cars on the track. In many places the statement is made that locomotives and cars tried to take a short-cut across the curves instead of following the track, whereas with flange lubrication this is not heard, for the reason that with a small amount of lubrication to the flange or inside head of the rail a considerable portion of the derailments would be eliminated.

The more friction between wheel flanges and rail the more train resistance is developed, and the higher the train resistance the greater the fuel consumption. This was not proven by actual pounds pull per ton, but from the fact that with flange lubrication and drifting down over the curves on certain stretches, more braking was necessary than when not using flange lubrication. On switching and shifting locomotives the greatest benefit will be derived, as they are continually going over crossovers and curves.

An examination of the rails on both curves and tangent tracks after a locomotive and train passed over with the locomotive equipped with one of the best lubricators showed that a thin film of oil was very noticeable on the inside of the head of the rail. When a heavy asphaltum oil is used, the deposit is enough to soil a white handkerchief if rubbed on inside of rails; therefore, as the average resistance in pounds per ton of a train on a 2-degree curve is about 0.58 lb. without lubrication, this figure would be somewhat reduced with lubrication on the flanges.

An extensive test was made with and without flange lubrication on one of the larger roads covering a period of two years, the first year with and the second year without flange lubricators. The locomotives equipped were run over the same section or stretch of track and everything was directly comparable. It was established on this test when using flange lubrication that the flange wear on the driving wheel tires was reduced 72 %, while the

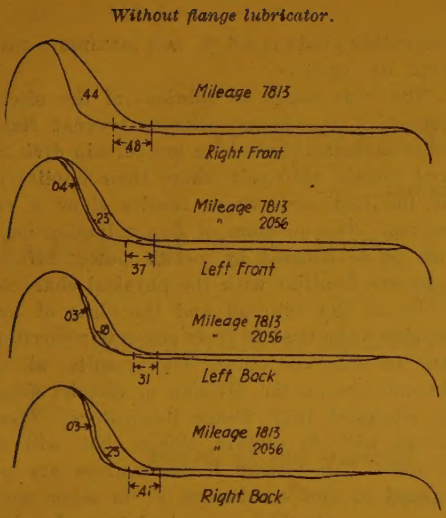

Fig. 6. — Locomotive driving wheel contours showing that without flange lubrication the flange wear is excessive when compared with the tread wear.

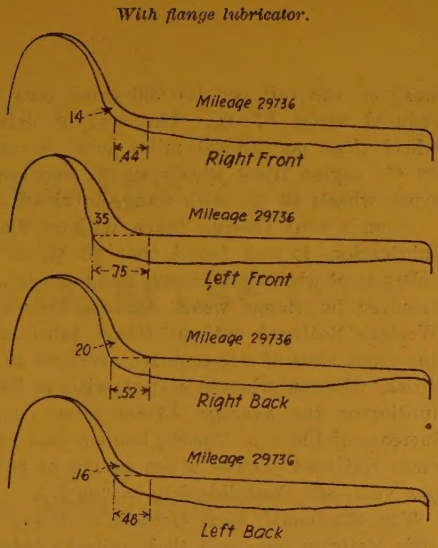

Fig. 7. — These driving wheel contours show that flange lubrication decreases the flange wear, thus allowing the tread to wear, and in a number of cases be the condemning factor. The mileage made by these tires for the flange wear shown is about four times that made by the tires in figure 6. The flange wear in figure 6 was greater than in figure 7.

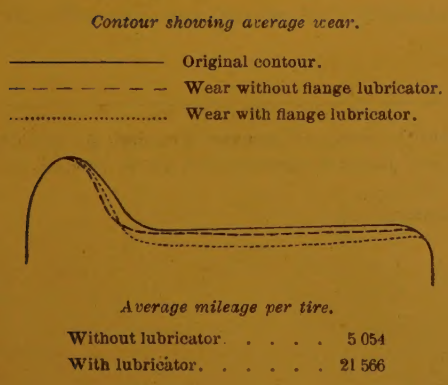
Contour showing average wear.
Original contour.
Wear without flange lubricator.
Wear with flange lubricator.
Average mileage per tire.
Without lubricator 5 054
With lubricator. 21 566

Fig. 8. — A composite diagram of the driving tires of several Consolidation locomotives with and without flange lubrication. This comparison readily shows the decrease in flange wear when using a flange lubricator.

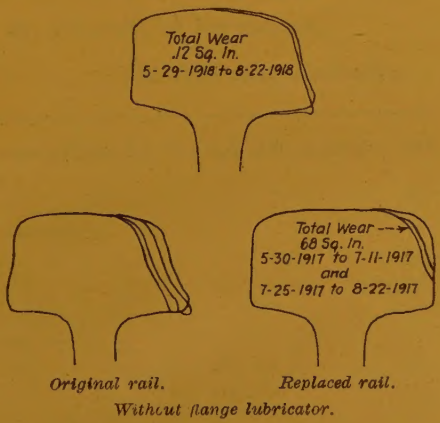

Fig. 9. — Comparative rail wear at the same location and over the same period of time with and without flange lubrication. It will be noted that the wear on the rail with lubrication was about 17 % of that on the ones without lubrication. The derailments on a portion of this stretch over with the above tests were made showed a decided decrease when flange lubrication was used.

wear on the rail per 100 000 gross tons was reduced about 87 %. The cost of driving wheel tires per 10 000 miles was decreased 29 %, engine truck wheels 42 %, and tender truck wheels 49 %, with flange lubrication.

From actual records taken without flange lubrication, it was found that 80 % of the rolled steel wheels under cars and tenders were removed for flange wear. On the Norfolk & Western Railroad without flange lubrication, the front tires of a locomotive averaged 16 000 miles, whereas when equipped with a flange lubricator the average 33 000 miles, or an increase of 106 %. The St. Louis & San Francisco Railroad showed a net saving of $84.03 per year per Consolidation locomotive.

The Cincinnati, New Orleans & Texas Pacific Railway increased their mileage between turning tires from 23 000 miles before using lubrication to 44 000 miles after using lubrication on the flanges. On their Pacific type locomotives the mileage between turning tires was increased from 40 000 to 92 000 miles. On a 2-8-0 Southern Pacific locomotive the life of the driving tires was prolonged 375 % when equipped with flange lubricators, the tender truck wheels 436 %, and rail wear on curve 250 %. This test was conducted where the ruling grade is 3.8 % and maximum curve over 10 degrees.

The wide range of opinions of the effectiveness of the flange oiler to prevent flange wear indicates that there are certain divisions and certain railroads where their application is justified and where results show a real saving. The question of flange lubrication is one to be decided by motive power officers, who are familiar with the physical characteristics of the railroad and the class of locomotive to be used in their respective territory, but in order to obtain best results, all the locomotives on the division or district should be equipped with flange lubricators. Flange oilers will do certain things, but will not prevent flange wear if locomotives are permitted to run « sideways »; in other words great care should be exercised in having locomotives properly trammed. With the proper flange lubricator and when using a heavy asphaltum oil the flange wear on the locomotive, tender and cars and rail wear will be sufficiently checked to warrant the use of flange lubricators, but no matter what flange lubricator is used, it must be maintained and receive the co-operation of everybody concerned.

[385. (06.111]

OFFICIAL INFORMATION

ISSUED BY THE

PERMANENT COMMISSION

OF THE

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

Award of the triennial « Arthur Dubois » Prize [1].

(1st award : 1920-1922.)

The special Commission appointed to examine the papers dealing with the science of railways which have been presented in competition for the prize instituted by the Permanent Commission in memory of the ex-President of the Association, Arthur Dubois, have made their award. They are unanimous in awarding the prize for the first triennial period — 1920-22 — to Mr. Richard Desprets, Chief Engineer to the Belgian State Railways.

We offer our very sincere congratulations to Mr. Desprets on his success.

The Executive Committee.

(1) The regulations governing the award of this prize were published in the May 1920 number (p. 310) of the *Bulletin of the International Railway Association.*